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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Advertisement, May 5, page 50.

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See Full Page Advt. page 58, May 5.

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See Advertisement page 35, May 12. 2402

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See half-page Advertisement page 66, May 19.

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It has been brought to our

notice that suggestions have been made to the effect that alien enemies have interest in this Company, and in consequence we desire to give public notice that such suggestions are untrue, and that our Board of Directors, Officials, and Shareholders are all natural born British subjects, no alien enemy having any interest, directly or indirectly, in the Company.

We also give WARNING that, should we trace the source of any such assertions, it is our intention to take action against the persons responsible for the same.

CUSTODIS LTD., E 316
By Order of the Board.

1916 B. 027.

IN THE HIGH COURT OF JUSTICE, CHANCERY DIVISION.
MR. JUSTICE YOUNGER.

In the Matter of BROWETT, LINDLEY & CO., LIMITED and REDUCED, and In the Matter of the Companies (Consolidation) Act, 1908.

Notice is Hereby Given that

a Petition presented to the High Court of Justice, Chancery Division, on the 8th May, 1916, for confirming the proposed reduction of the Capital of the above-named Company from £120,000 to £107,500, by cancelling capital which has been lost or is unrepresented by available assets, to the extent of 6s. a share in respect of each of the 50,000 Ordinary Shares which have been issued, is directed to be heard before Mr. Justice Sargant, on Tuesday, the 6th day of June, 1916. Any Creditor or Shareholder desiring to oppose the making of an Order for reduction of the Capital of the said Company under the above Act may appear at the time of hearing by himself or his Counsel for that purpose. Such person is required to give two clear days' notice in writing of his intention to appear, with the grounds of his objection, to the undersigned, the Solicitors of the Company. A Copy of the Petition will be furnished to any person requiring the same, by the undersigned Solicitors, on payment of the regulated charge for the same.

Dated this 22nd day of May, 1916.
R. T. WATKIN WILLIAMS, E 333
Master of the Supreme Court.
VIZARD, OLDHAM, CROWDER & CASH,
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Agents for Browette, Coventry,
Solicitors for the Company.

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(UNIVERSITY OF MANCHESTER).

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16th May, 1916. E 294

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ON REDUCTION GEARS.

By JOHN H. MACALPINE.

(*Continued from page* 480.)

Origin and Trials of the Floating Frame.—In 1904 the late Admiral George W. Melville and the writer visited Europe to examine, for the late Mr. George Westinghouse, the marine-turbine situation. He was also in Europe at this time and we were frequently together. In discussing the question we often advised him that, in our opinion, gearing offered the only hopeful solution which would make the turbine applicable to ships of moderate or slow speed and greatly improve their application to fast ships. But if the gearing was to be of practicable size the pinion became so broad in proportion to its diameter that it was quite evident there would be a great delicacy of alignment, which would limit seriously the power which could be transmitted safely. Hence we made no direct reference to gearing in our report. But later a rigid-gear design was made, and a close study of this made it increasingly certain that the rigid gear left much to be desired. It also became evident that if the pinion could be put under the control of the large gear, except as to its rotation on its axis, delicacy of alignment might be overcome. Only long-continued study showed how perfectly this could be accomplished. Hence the floating frame developed, and what I have said in the foregoing shows how complete the solution is, not only regarding alignment, but in diminishing the effects of torsion. The condition required is that the moments of the tooth pressures, and therefore also those of the bearings, must be zero about some point I between the helices, and preferably in the centre. This cannot be accomplished by any other mode of suspending the bearings or by making the large gear flexible.

The first idea of the floating frame suggested itself towards the end of 1905, but did not fully develop for a considerable time thereafter. We submitted it to Mr. Westinghouse in a drawing dated September 26, 1906, which shows the floating frame, pinion, and I-beam, almost identically as they were made in the experimental gear; the flexible shaft and loose coupling driving the pinion developed later. Mr. Westinghouse was immediately struck by the advance this opened and asked us to make a complete design of a gear which he could test. This we at once did, but the building of it was delayed by various circumstances, especially by the panic of 1907. After the exceptionally successful trials of 1909 Mr. Westinghouse wrote in the "Broadening the Field of the Marine Steam-Turbine"—a volume privately but widely distributed—page 10:—"The certainty with which the floating frame of the Melville and Macalpine reduction gear operates to maintain an evenness of tooth pressure and the limitation of the maximum pressure to 450 lb. per inch of tooth contact with a load of 6000 horse-power coupled, with a large factor of safety, at once removes this invention from an experimental to a completely commercial apparatus.

"I regard this invention as epoch-making in its importance. It has been my privilege to supply the material things which were needed to transform the creature of Messrs. Melville and Macalpine's imagination into an actual thing of iron and steel. The results achieved by the completed machine have fully justified my faith in its ultimate success."

Necessity for Very Accurate Gear-Cutting.—It has sometimes been supposed that it is sufficient to give the pinion end play, but, as we have seen, this only divides the power equally between the two helices, it does not otherwise condition the distribution of tooth pressure. If a pinion is out of line, end play alone cannot possibly improve the alignment. Messrs. McLaren and Welsh see the difficulty very clearly, saying:—"In cutting the teeth of gear-wheels and pinions very great precision is demanded in order to secure silent running, and a proper distribution of the load across the whole width of the engaging faces. It is therefore evident that the attainment of this necessary degree of accuracy becomes very difficult when the load to be transmitted by the teeth is considerable, and involves the use of a large wheel having a broad engaging face. This difficulty may be further increased by the fact that if a pinion bearing heats up, the resulting axial expansion of the pinion will cause a large part of the load to be transmitted by only a few teeth." This is emphasised again by them a few pages later in the case of some of the broadest gears in the examples they give, and they then propose dividing the gear into two, as already noticed, to avoid this difficulty.

I wish to call special attention to the fact that the only reference to inaccurate gear-cutting which I have so far made occurs in the above quotation. I do this for two reasons.

1. Because it is very commonly supposed that this is the only difficulty requiring to be overcome. What I have said under (*a*), (*b*), (*c*), and (*d*) entirely contradicts this.

2. Because many think that the floating frame was introduced to counteract, in some way, the effects of bad gear-cutting. That the reason for its adoption was to overcome delicacy of alignment is fully and clearly stated in the article in ENGINEERING, vol. lxxxviii., page 377, already referred to; and in that article imperfect gear-cutting is not once mentioned. Our stand regarding the necessity for high-class tooth-cutting is shown by the following quotation from a letter of July 23, 1907, to Messrs. Schuchart and Schutte from my firm, Melville and Macalpine, before their offer to cut the gears was accepted:—"Extreme accuracy of tooth is the one requisite in the reduction gear. Would it be possible with your gear-cutting machine to finish these teeth, either by milling or grinding, with a maximum error well within $\frac{1}{1000}$ in.?" They gave us assurance of accuracy. Later when, from letters which passed, we thought that possibly the contract might be sublet, we wrote: "The success of the reduction gear depends so entirely on the extreme accuracy of the cutting of the teeth that we would like you to assure us that no part of the work will be done by outside parties."

Although the tooth-cutting was of very high class, it was not quite so perfect as we, perhaps unreasonably, hoped. A slight vibration of the floating frame was visible, the total movement of the ends being about $\frac{1}{100}$ in., which would give rise to inertia forces raising the mean tooth pressure per inch by a small fraction of 1 per cent. at full power. It may be that this freedom of the floating frame eased the effect of the irregularities, but it is difficult to tell. Most or all of this slight residuum of error can be obliterated by fixing the floating frame when running under light load and using emery and lard to grind the teeth, or scraping the markings after the run. Thereafter the floating frame continues its proper function, without any vibration, of maintaining good distribution of tooth pressure.*

It will be interesting to show how perfectly this is accomplished. The first floating-frame gear sold by the Westinghouse Machine Company was started at the works of the Commonwealth Steel Company, Granite City, Illinois, on March 31, 1911. This was used to drive a direct-current generator by a low-pressure turbine. It was rated at 736 horse-power, but to take a 25 per cent. overload. The pinion is 5.55-in. pitch diameter, operating at 3600 revolutions per minute, giving a power constant of 1.20 at rated load. Mr. R. A. Bull, the general superintendent, wrote me in February, 1912, that it was in continuous service five days and five nights a week, giving "perfect satisfaction," at a variable load, 25 to 140 per cent. of its rating—corresponding to power constants of 0.30 to 1.68—the average being about 85 per cent. of its rating, and that the tool-marks were still visible in places on the teeth after more than ten months of such service; also that the gears made no more noise than when first installed. To properly interpret this, I should say that the shop tests had brightened the teeth at once, all along, over a considerable fraction of the bearing area, leaving tool-marks of only imperceptible depth; also, the sound of the gears could only be heard when standing immediately beside the gear-case—moving to one side or another caused it to be entirely drowned by the noise of the turbine or generator. This gear still continues to give the same satisfactory service and has never given any trouble or required any repair.

The power constants have been much raised since this early gear was put in service, and now a pinion of 5.196 in. in diameter at 3600 revolutions per minute is supplied to drive a 1000-kw. generator guaranteed to carry a 25 per cent. overload. This overload brings up the power constant to 3.66.

One objection has been raised which it is well to notice. It has been feared that the floating frame would be forced into dangerous vibration about the centre I. But the pinion cannot vibrate thus further than those minute movements due to the slight inequalities of the teeth which may remain. Greater vibrations are prevented by the engagement of the pinion with the gear which is carried in fixed bearings.

Data of Power Constants, &c.—I will now give the promised data from gears that have been built, are under construction, or have been proposed.

All the floating-frame gears have been built by the Westinghouse Machine Company, licensees of the Westinghouse Gear and Dynamometer Company. In January last there were in operation:—

Number of gears	90
Total horse-power at normal rating	80,245
Total horse-power at overload rating	99,190

All of these gears have given exceptionally satisfactory service.

The gears then being built, or built but not yet in operation, were:—

Number	35
Total horse-power at normal rating	104,100
Total horse-power at overload rating	118,535

A considerable proportion of the gears installed and about 75 per cent. of those building are for marine applications.

The table on the next page gives data of various gears, with and without floating frames, and the power constants. Though some of those given have only been tested in the shop or are proposals, experience from gears in service shows that, with a floating frame, power constants of 3.5 and 4.0 are perfectly safe.

U.S. Collier Neptune.—I would like to clear away the misapprehension regarding this ship. The ship failed to come up to her contract speed on her endurance trial, and the Official Trial Board reported against accepting her turbines and air-pumps, but approved the gears which had acted perfectly. The power constant of these at 4000 horse-power per gear, for which there was ample boiler power—this power was actually exceeded on the standardisation trial at a speed above contract requirements—and 1220 revolutions per minute of pinion and turbine, was assumed the same as that of the experimental gear at 10,000 horse-power and 1500 revolutions per minute of pinion. We had only been able to test the experimental gear to 6000 horse-power, but it was so evident that the rated load could be increased that this somewhat long leap was decided on. It brought the power factor up to 2.43. The Neptune's pinion was therefore made 11 in. in diameter.

When new turbines had to be made, the Navy Department desired the propeller speed reduced from 135 revolutions per minute, as in the first installation, to 110, corresponding with that of the sister-ship Jupiter. Probably now double reduction gears would be adopted, but the late Mr. Westinghouse determined to reduce the pinion to 7 in. diameter, running at 1910 revolutions per minute. These gears are now in the ship which

* That bad tooth-cutting cannot be compensated by *any* device may be very simply shown. Suppose we have a perfectly cut gear, and pinion with helical teeth. We may simulate very bad tooth-cutting by filing back portions, or the whole, of one tooth by $\frac{1}{100}$ in. When the gears are running many teeth are in mesh at one time, and those not filed back would entirely prevent the filed parts from coming into contact. To cause contact in spite of any such irregularity we would have to deal with each short length of each tooth separately giving it a great elasticity by means of springs or other independent adjustment. Some such devices have been proposed. While we find as wonderful adjustments in Nature, they are far outside of the range of practical engineering.

Table of Gear Data.

Reduction Gear.	Kind.	Horse-Power per Gear.	Pitch Circle Diameter of Gear.	Pinion. Number per Gear.	Pinion. Pitch Circle Diameter.	Pinion. Axial Length of Helices = 2 h.	Pinion. Number of Teeth.	Pinion. Revolutions per Minute.	Pinion. Power Constant.
			in.		in.	in.			
A. Hope Natural Gas Company	Floating Frame	3400	120.089	1	10.007	40	25	1500	2.26
B. Cleveland Electric Illuminating Company	,, ,,	5500	99.689	1	10.392	40	26	1800	2.72
C. U.S.S. Melville	,, ,,	4000 total 2000 per pinion	95.550	2	7.794	32	26	1400	3.02
D. Cruising gears for U.S.S. Arizona	,, ,,	2000	78.520	1	6.351	24	21	2500	3.12
E. Standard 1000-kw. gear (normal rating)	,, ,,	1850 (with overload)	25.595	1	5.106	20	26	3600	3.66
F. Cruising gears for U.S.S. Pennsylvania	, ,,	1600 total 800 per pinion	69.474	2	4.811	22	24	1800	3.99
G. Swedish Twin - Screw Cruisers	,, ,,	5500 h.p. 5500 l.p.	129.326	2	7.506	31	25	3600	3.61
H. W. M. Co. Proposals for recently-let U.S. torpedo-boat destroyers(I)	,, ,,	8500	48.5	1	9.9	39	26	2200	3.98
H. Ditto ditto (II)	,, ,,	4250 h.p. 4250 l.p.	53.1	2	6.64 h.p. 6.64 l.p.	27	23	3600	4.03
H. Ditto ditto. Offer by manufacturer of rigid gears	Rigid Gear	4500 h.p. 4500 l.p.	66.0	2	10.75 h.p. 17.5 l.p.	27	Not known	2750 h.p. 1689 l.p.	1.32 h.p. 0.497 l.p.
I. Vespasian..	,, ,,	1095 total 547.5 per pinion	99.5	2	5.0	24	20	1459	3.00
J. S.S. Transylvania and Tuscania	,, ,,	5450 per gear 2725 per pinion	Nearly 120	2	9.6	About 48	About 33	1707	1.80
K. S.S. Ciudad de Buenos Aires and Ciudad de Monte Video	,, ,,	2900 per gear 1450 per pinion	54.275	2	6.233 h.p. 8.831 l.p.	About 28	Not known	2320 h.p. 1630 l.p.	2.58 h.p. 1.29 l.p.

A. This gear transmitted the power to gas-compressors, and as the torque from these varied greatly per revolution the power constant was kept low. It is not needed in the summer. It was put under load on November 1, 1914, when it ran continuously, except for about two hours each week, at 3400 horse-power till shut down for the summer, on May 31 of this year.

B. The first of two gears was started on December 4, 1912; the second on January 20, 1913. The power given is the guaranteed 25 per cent. overload.

C. This ship has just completed her official trials. On the standardising trial she developed 4280 shaft horse-power at 1350 revolutions per minute, giving a power constant of 3.35. On the 48-hour endurance trial she averaged 4100 shaft horse-power at 1350 revolutions per minute, giving a power constant of 3.21. The operation was highly satisfactory in every respect.

D. These have been tested in the shop for one hour at 2330 brake horse-power and 2597 revolutions per minute of pinion, giving a power constant of 3.50; and for 10 hours at 2000 brake horse-power and 2374 revolutions per minute, giving a power constant of 3.29.

E. There are three of these in service, the first having been put in operation on October 2, 1914. The horse-power given is the guaranteed overload capacity, with allowance for the efficiency of the generator.

F. This has been tested in the shop for 10 hours at 1600 brake horse-power and 1733 revolutions per minute, giving a power constant of 4.15.

G. These are at present under construction for two Swedish warships, of 22,000 horse-power each.

H. The machinery for these ships was awarded to bids offering direct-connected turbines. No doubt in the rigid-gear bid the centres of the pinions were fixed to accommodate the turbine design adopted. Otherwise the power constants would undoubtedly have been higher.

I. The Vespasian's geared-turbine machinery was built by the Turbinia Works Company and was put in commission in February, 1910. The figures given in the table are from the highest run of the progressive trials of April 11, 1910 (see Transactions of the Institution of Naval Architects, 1910, page 172). The average service speed of the ship is given as about 9.3 knots (see Transactions of the Institution of Naval Architects, 1911, Part I., page 32). From the diagrams we find the corresponding power and pinion speed to be 630 total and 1363 revolutions per minute respectively. The corresponding power constant is 1.85. The helical angle is 20 deg.

J. Though these ships were by different builders, the turbines and gears are said to be identical. The published data is not quite full (see Engineering, vol. xcviii., page 538, and vol. xcix., pages 184 and 187.) The pinion diameter given is probably very nearly exact; the axial length of helix and number of teeth in the pinion are more indefinite. The power is taken from the highest trial-run of the Tuscania, no doubt above the service power of the ship. The helical angle is 44 deg

K. The data given is from the article and drawings in Engineering, vol. xcviii., page 745. The power and revolutions and consequent power constants are from the official measured-mile trial. There is an unimportant discrepancy between the ratio of the pinions and the ratio of the revolutions, the former no doubt being correct. The drawings show a helical angle of about 45 deg.

will soon be tried. The shop tests gave most notable results. The two sets were coupled large gear to large gear. The pinion of one was driven by a turbine, and in the other gear the pinion was driven by the large gear, which is by no means the most favourable condition. This pinion actuated a water brake. The highest power transmitted was 3600 brake horse-power for about one hour at 2030 revolutions per minute of pinion. This gives a power constant of 5.18. It was operated for about six hours at from 3200 to 3600 horse-power. The teeth were found to be in excellent condition. This highest power will drive the ship considerably above the contract speed. This very remarkable result was obtained with a value of $2\ h/D = 5.15$. There is no reason to suppose the power transmitted is a limiting value, and I believe the safe load could still further be raised by restricting $2\ h/D$ to 4 or rather less. Though the 6000 horse-power transmitted by the experimental gear was considered a remarkable result at the time, and it was the highest safe load we hoped for, yet a power constant of 5.18 is equivalent to raising this 6000 to 21,350 at the same pinion speed, 1500 revolutions per minute.

Thus the Neptune's gear trials, instead of being a failure, as many have believed, have actually given far the highest and best results yet attained. The Neptune ran her standardising trial on November 17. The same day she commenced her twelve-hour full-power trial. The average results of this latter trial were:—

Speed	14.28 knots
Shaft horse-power	7175 total
R.P.M. of propellers	115.34
R.P.M. of pinions	2003
Power constant	5.22
Coal per shaft horse-power ...	1.528 lb. per hour

The machinery acted admirably throughout the trials. The guaranteed coal consumption per shaft horse-power is 1.8 lbs., but while the trial result is fully 15 per cent. under the guarantee, it is considerably above what can now be accomplished. The designs of neither the first nor the second set of turbines for this ship were made by the leading turbine men of the Westinghouse Machine Company. They did not approve of them, and did not expect them to attain good efficiency. The water for the turbines only was 13.4 lb. per shaft horse-power hour, and for all purposes 15.8 Founding on a guarantee made by the Westinghouse Machine Company for marine machinery, they are now building (see Fig. 8, given later in this article), the consumption of the turbines only in the case of a large ship should not exceed 10.8 lb. of water per shaft horse-power hour, and they confidently believe that there is a comfortable margin in the guarantee. This is 19.4 per cent. under the result attained by the Neptune.

The Neptune's sister-ship, the Jupiter, which has a turbo-electric drive, showed on her full power trials a coal consumption per shaft horse-power of 1.664. This excess over the Neptune's result is in part due to inferior firing and less economical auxiliaries; but the loss of efficiency in transforming the work of the turbine into electric energy, and its re-transformation by the motor, is an important contributing cause.

The first design of turbine built for the Jupiter was rejected after trial, and an improved design adopted. This latter was so satisfactory that the builders, the General Electric Company, improved all their commercial designs to correspond. (See *Journal of the American Society of Naval Engineers*, vol. xxvi., pages 347, 348.) The Jupiter's full-power water rate per horse-power hour, the power being measured by a torsion-meter on the propeller shafting, is 11.68 lb. for turbines only, or fully 8 per cent. worse than the Westinghouse Machine Company's guarantee. This is precisely what one would expect; for, with equally well-designed machinery, the geared turbine will always show a considerable economy over the turbo-electric drive; the auxiliaries are practically the same; the loss of power in the gear transmission is from 1 to 2 per cent.; while the double conversion of energy in the turbo-electric drive must entail a minimum loss in the neighbourhood of 10 per cent., and sometimes a good deal more.

When the power is reduced, even to 25 per cent. of full load, Fig. 8, already referred to, shows for the geared turbine a very slight rise of steam consumption, at least equalling the performance of the electric drive in this respect. And in no respect does the electric drive surpass the geared turbine. The latter reverses as promptly, with less manipulation, and with ample power—more than 50 or 60 per cent. of full ahead power cannot be used in going astern or the engines will race; the geared turbine is the simplest steam system, while the turbo-electric is the most complex, with a complexity almost forbidding; the geared turbine is simpler in operation, and requires only steam engineers, while the electric drive demands men who are both steam and electric engineers; the geared turbine main drive is many per cent. — in some cases 30 per cent. — lighter, and occupies less space; it is not readily liable to total disablement from water, as is admitted to be the case with the electric drive; finally, it has a simple oil cooling system, against the large air-ducts of the electric drive, which have to carry off about 10 per cent. of the power, and may readily convey water or moist air to the generator and motor. I do not know of any good excuse for the adoption of electric drive on board ship.

(To be continued.)

THE INSTITUTION OF MECHANICAL ENGINEERS.

On Friday, the 19th inst., the last ordinary general meeting of the 1915–16 session of the above Institution was held at the Institution of Civil Engineers, Great George-street, Westminster, the President, Professor W. C. Unwin, F.R.S., occupying the chair.

New Honorary Member.

The formal business of the meeting having been transacted, the President announced that the Council, acting under the powers conferred upon them by the Articles of Association, had nominated Sir Alfred F. Yarrow to be an honorary member of the Institution. Sir Alfred had, he remarked, long been an ordinary member, and the Council considered that the time had come to place him on the list of honorary members. Sir Alfred had had a distinguished career as an engineer, and he had taken a great part in the development of fast destroyers, while his boiler had been fitted in all the later types of warships. In research work he had done much, particularly in investigating the effect of depth of water on the speed of ships. Perhaps, however, the principal reason for recognising his merits was in the fact that he had done so much for the country in various ways. He had, for instance, at his own expense, established at Bushy the admirable and well-known tank for experimenting with ships' models, probably the best of all such tanks that had been built. At Bushy models were tested and suggestions made for the improvement of the lines of ships, which, as the speaker knew personally, were saving considerable sums to the builders. In addition, Sir Alfred had established at Broadstairs an admirable convalescent hospital, now being used for wounded soldiers, and in many other ways had been exceedingly generous in helping the country during the present time of stress.

The President further announced the purchase by the Council, acting under their powers, of an oil painting bearing date 1736. This painting represented one of the very earliest experiments with steam navigation, and showed a tug built by

Jonathan Hulls, equipped with a Newcomen engine, working through ratchet gear to drive the paddle-wheel. Of course, at that period nothing really serious had been done in steam navigation, but the experiment was very interesting.

The Secretary then read the ballot list for the election of members, from which it appeared that 87 candidates had been duly elected. Seven transferences had also been made from the class of associate member to that of full member.

SPUR-GEARING.

The paper set down for reading and discussion was one entitled "Spur-Gearing," by Mr. Daniel Adamson, member, of Hyde. This paper we commence printing in full in another part of the present issue, and accordingly proceed to the discussion.

This was opened by Mr. H. Hubert Thorne, who remarked that the subject of the paper was particularly interesting to him, since he had devoted a large part of his time and engineering experience to the question of gearing. Mr. Adamson had observed that there was no need to give much consideration to the question of outline on account of the exhaustive work carried out by engineers in the past. The speaker would say that the consideration which Mr. Adamson had himself devoted to this question afforded clear proof of the fact that it was by no means exhausted, and that much remained to be said. He regretted that the author had confined himself to straight-tooth gears, because he (the speaker) did not, in view of the rapid advances of the last few years, consider the subject complete without some reference to helical gears. Mr. Adamson had mentioned Bruce's advocacy of a greater pressure angle to increase the strength of teeth, it being stated, in support of the advantage to be gained by this increase, that engineers could thus use a finer pitch and, consequently, more teeth; a greater number of teeth would be in engagement at one time. The speaker regarded this contention as correct, but it appeared to him that those who had given preference to the double helical, rather than the straight, form of tooth sought to achieve the desired end in a much better way. In the case of the double helical tooth-gear, by increasing the face width it was possible continually to bring in more and more teeth. With the straight-cut tooth, no matter how the face width was extended, the conditions of engagement of the tooth could not be in any way improved. The author had referred to Lasche's recognition of the effect of rate of curvature of the surfaces in engagement on the breadth of the line of contact, and, in the speaker's judgment, this part of the subject had not received the consideration it deserved from engineers generally. He thought it apparent that Lasche was correct in his contention that, with small curves, the lubricant used was readily displaced, and, in designing gears, consideration should be given to this fact; where very small pinions, and consequently small curves, were used, the face width should be increased, in order to allow for the factor alluded to. The speaker's firm took that factor into consideration in the design of gears.

Mr. Gerald Stoney agreed with the last speaker that it was a great pity that the author had not dealt with the modern developments of gearing. These developments, as exemplified in the application of geared turbines, especially for marine work, had made enormous progress during the last few years. Powers of over 10,000 horse-power per pinion, pitch velocities of between 6000 and 7000 ft. per minute, and pressures up to 700 or 800 lb. per inch were now in common use. This enormous development had been rendered possible entirely by the use of very accurately cut helical gearing, and the speaker considered that the introduction of such gearing had completely revolutionised the use of gears, such powers being totally unprecedented in former days. For smaller powers, such as required for geared pumps, &c., helical gears, accurately cut, were very largely used in place of raw-hide pinions, which hitherto had been employed to a considerable extent. He believed that in the future, for a great deal of work, helical gears would be used exclusively, instead of straight-cut gears. Mr. Stoney pointed out that the probable total inaccuracy of pinions, for a pitch velocity of 6000 ft. per minute, was something of the order of one-thousandth of an inch. This is the maximum deviation at any point of the pinion from the truth, the inaccuracy between any two teeth being vastly smaller. The possibility of getting such gears to run silently at such high speeds was dependent on exceedingly accurate cutting; considerable difficulty had been met with in getting such gears to run silently, but by the use of accurately-cut gears, such as were made by several firms in this country, the difficulties had been completely overcome. [Mr. Adamson here inquired as to the pitch of the gears referred to, Mr. Stoney replying that the usual pitch was about 0.815 in.]

Mr. Walter J. Iden referred to the fact that the author had not touched upon the question of grinding gears after they were hardened. Grinding gears to their true form, after hardening, was a process now used in connection with motor construction.

Mr. Arch. Sharp, whose communications to the Institution of Civil Engineers had been referred to by the author, explained that his knowledge of the subject under discussion was practically confined to the mathematical side. In those communications the speaker had endeavoured to carry out suggestions derived from the text-books of Professor Unwin, and to tabulate a series of circular arcs that would be of practical use to the draughtsman in laying out such gears as the author had dealt with. He might generalise his views as to the accuracy of the form of the teeth in saying that the tooth form was of very little importance compared with accuracy in carrying out the work. In other words, to make a mathematically accurate wheel, or pair of wheels, of correct theoretical form, as satisfied by the well-known involute or cycloidal forms, it was necessary that each tooth should be an exact replica of every other, and all must be of exactly the same pitch. The speaker had investigated the errors due to the substitution of circular arcs for true curves, and he would take at random an example from the tables that formed the appendix to his paper. Taking a pair of wheels geared 1 : 3, with 16 teeth in the smaller wheel, the maximum error due to the circular arc outline, instead of the theoretically accurate one, was 0.38 of 1 per cent. From another part of the speaker's paper, it appeared that an error of 1 per cent. in the velocity ratio corresponded to an inaccuracy, at one part or other of the tooth outline, of one-thousandth part of an inch. He ventured to suggest to Mr. Stoney that the inaccuracy in the case to which that gentleman had referred must be much closer and finer than the limits stated, and would probably be measured in ten-thousandths of an inch, or fractions thereof. The author had referred to Lasche's work on the errors due to displacement of tooth outline. It was a well-known fact that the greater the number of teeth in a pair of wheels the more smoothly they worked. One result of the speaker's paper was that, in the tooth forms discussed, the magnitude of error varied inversely as the cube of the number of teeth. Referring again to the pair of wheels with 16 teeth to the pinion, if the number of teeth were increased to 32, the error would be reduced to $\frac{1}{100}$ of 1 per cent. In that, the speaker considered, was a mathematical accuracy greater than the errors due to the best results with mechanical grinding. With regard to the general laying out of the tooth outlines of a pair of wheels for mill-gearing that had to be designed *de novo*, the speaker did not think that engineers had paid sufficient attention to the dicta laid down by Mr. Michael Longridge—*i.e.*, that nearly all teeth were made too long in the addenda. If engineers would be content with a shorter tooth, each tooth—acting as a cantilever—was in a much better form to resist the bending stresses at its root. In this way the bending moment was reduced, as were also the thicknesses and the pitch, while the number of teeth would be increased. As he had said, the point deserved greater attention; indeed, if Mr. Stoney, or someone else, would give particulars as to tooth outline, and other data relating to geared turbines for very high pressure, these would constitute a valuable supplement to the paper.

Mr. Walter Pitt inquired whether it was not a fact that, where it was desired to have cutters that would cut wheels which would gear with a uniform velocity ratio, either a cycloid, with generating circles for the tops and bottoms of teeth of equal size, must be used, or else straight-sided racks, with involute teeth. The moment a departure was made from the straight-sided rack, as would be the case when trying to cut too small a number of teeth with the involute, the result would be fouling. It had been remarked that the cutters of one firm were a trade secret. He would ask whether that was not a simple case of "fudging" the curve to get rid of the fouling. When the rack was fudged, it was no longer a straight line, and the velocity ratio had to be dropped. Was this not one of the reasons accounting for inertia difficulties? A previous speaker had observed that with helical gearing more teeth could be got into contact than in the case of straight teeth. The speaker was strongly in favour of helical gearing; but did the increase of breadth of helical gearing increase the number of teeth in contact? Was not a simple displacement of the same profile taken in different positions? He was of opinion that much of the trouble with involute teeth arose from trying to set wheels with too small a number of teeth on the pinions. In his schooldays he was told that involute teeth could not be cut with less than 20 to 30 teeth in a true involute. Any departure from that involved fudging.

Mr. W. E. Sykes considered the subject of the paper both interesting and important. Some of the author's remarks provoked criticism; while many might have been justified in the past, conditions had altered so much recently as to bring about a complete change of ideas. With regard to wear, the author seemed to imply that short teeth were considerably better than long ones. This view was generally accepted as correct, but the speaker doubted, in most cases, the advantage of shorter teeth. The pressure angle was another question calling for considerable investigation and discussion. For a number of years the 14½ deg. pressure angle was regarded as correct practice, but more recently a pressure angle of 20 deg. had been advocated and, to a great extent, adopted. Not many engineers, however, had adopted a larger angle. A pressure angle of 22½ deg. had been used, and, according to all published reports, had been used with satisfaction. It might interest members to learn that for some time past turbine gears run at the speeds and with the powers indicated by Mr. Stoney had been made with a pressure angle considerably greater than 22½ deg.—in fact, approaching 28½ deg. These gears had been transmitting power and working constantly at their designed load for something like twelve months, with every success. It would therefore appear that pressure angles might be increased with great advantage. Reverting to length of tooth, with a pressure angle of 22½ deg. he had not found in practice that it was necessary to alter the length of the tooth below the standard proportions for double helical gears, which, he might remark, were shorter than the Brown and Sharpe standard. Mr. Sharp had contended that gears with the larger number of teeth ran more sweetly than those with small numbers, but the speaker would assume that Mr. Sharp had not meant this contention to apply to helical gears, because pinions with seven to fifteen teeth were frequently used, and were found to run as sweetly as could be desired. The author had quoted statements to the effect that revolving masses should not be rigidly connected to pinion shafts. In this relation the speaker would point out that at least one well-known firm had adopted the practice of coupling the flywheels to the pinion shafts of very heavy rolling mills in order to overcome the peak loads. This had been applied to mills up to 500 horse-power, and such gears had been running quite successfully since 1911. No doubt when the statements quoted were made the art of gear-cutting had not reached its present stage. On the question of the curves of gear teeth, he gathered from the discussion that this matter was a little misunderstood. At one time it was commonly held that teeth should be either cycloidal or involute. The speaker would like to refer those interested to Grant's book, which fully explained the matter. Grant there stated that for teeth to be correct they needed merely

to be odontoidal. This condition could be met either by the cycloidal or involute tooth, or by many other forms. The involute tooth was adopted at the present time because its curve could be generated with comparative ease by mechanical means. The paper and discussion did not seem to deal with the question of the theoretical generation of teeth. The turbine gears now made were, for the most part, generated by the hobbing process, with excellent results. The hobbing process might be regarded as theoretically accurate, and answered all practical purposes for moderate requirements. Other processes had, however, been invented, employing shaping tools, instead of the milling process with hobbing. By the shaping process the teeth of cutters could be accurately produced. That was to say, after the cutters were hardened, the teeth could be ground mathematically accurate. He had taken up generation by means of shaping tools some five years ago, and had since developed a new process, which would shortly be described in the technical Press. He might say, however, that the cutters used were in the form of a single helical pinion, and, after hardening, were ground by a particular mechanical method, which undoubtedly produced an involute curve without the slightest modification. The helical teeth produced had pointed apices, and were practically correct in every respect. The question of departing from the involute had been raised by Mr. Pitt, but the speaker considered that an incorrect impression was conveyed by saying that when straight-sided racks could not be used the involute must be departed from, as after exhaustive investigation it appeared to him that there was no reason why the straight-sided rack should not be used in generating processes. Mr. Pitt had further raised the question of the number of teeth in engagement with increasing face width in helical gears, but the speaker would say that there was no doubt whatever that in the case of helical gears it was possible to get a very large number of teeth in engagement merely by increasing the width of the tooth.

Mr. Holroyd Smith was the next speaker. After commenting upon the way in which modern instruments had robbed the old millwright of his handicraft, he referred to the personal satisfaction he derived from the author's statement that durability was dependent upon accuracy of construction as much as upon correctness of design. In the speaker's early experience this accuracy of construction was exceedingly difficult to obtain, and to produce well-made wheels he had adopted the plan of eliminating, as far as possible, the decimal points which figured in modern text-books. He preferred to reduce measurements to something definite, such as $\frac{1}{8}$ in. He recalled having to make wheels that should run smoothly and noiselessly at high speed. He had decided upon the involute type as being much preferable to the cycloidal; in fact, he believed he was one of the earliest advocates of the use of involute gearing in practice. When it came to designing the involute tooth according to the mathematical theories and formulæ in the books then existing, he saw that it would be hopeless to get any pattern-maker or founder to do it accurately by the aid of compasses. He accordingly made a drawing based upon careful study of the matter. Having first set out the tooth in the correct theoretical manner for the involute, he endeavoured to see how nearly he could approach that by setting his radial line, and striking that line by some measure that could be taken by the ordinary compasses. He succeeded in describing a curve of $2\frac{1}{2}$ in.; there were no decimals. He produced in this way an exceedingly smooth and perfectly running wheel, as nearly as possible like that represented by the author in Fig. 8 of his paper. In this connection, Mr. Holroyd Smith narrated the circumstances in the case of a works in which, by the substitution of these involute wheels, made according to the method he had just described, for wheels of an older type, comparatively noiseless running had resulted, and the menace of litigation had been removed.

Mr. Walter Pitt, speaking a second time, observed that he was quite aware that the rack might be made of any shape desired, with any curve as its true mating curve to get uniform velocity ratio. Was it not the case that if wheel A were cut off a given rack, and wheel B were cut off a given rack, A would gear with the rack and B would gear with the rack; but if it were desired that A should gear with B, the rack must be straight-sided?

Mr. Daniel Adamson then replied briefly to the discussion, promising to deal more amply with it in his written reply. Mr. Thorne had raised the question of helical gears, and in answer the speaker would say that he intentionally avoided referring to these gears in the paper, as it was not his object to discuss helical *versus* straight teeth. Objections could be raised to helical gear, just as advantages could be claimed for it. Judging by certain long articles appearing in ENGINEERING, the helical-gear people seemed to be well occupied in looking after themselves or in watching one another. The speaker's object had been to endeavour to show the correct principles, and if these were thoroughly understood they could be applied equally well to the straight tooth or the inclined tooth. Mr. Stoney had mentioned an example of pitch velocity of 6000 ft. per minute, very much higher, of course, than the velocities which the speaker had referred to in his diagrams. He agreed with Mr. Sharp in thinking that Mr. Stoney must have been in error in regard to the amount of inaccuracy involved.

Mr. Stoney here pointed out that the $\frac{1}{10000}$ in. he had mentioned would be between any two parts of the wheel, and not between adjoining teeth—*e.g.*, there might be large wheels, up to 14 ft. in diameter, with no part more than $\frac{1}{10000}$ in. from the truth. Mr. Adamson admitted that that would make a great difference. His experience in the case of adjacent teeth showed the error to be in the neighbourhood of $\frac{1}{10000}$ in. to $\frac{5}{10000}$ in.

Mr. Walter Iden had spoken of the grinding of gears. He (Mr. Adamson) had not studied the grinding of gears, but he imagined that the involute shape would be used, so that the sides of the teeth could be ground with the straight-sided wheel corresponding with the rack cutter which had been mentioned. Mr. Sharp had alluded to possible errors in pitch, or possible errors in angular velocity ratio, which might follow the adoption of his (Mr. Sharp's) circular arcs, correctly expressing the fact that the error due to the adoption of the circular arc would be much less than the errors quoted in the paper. But, as the speaker had said, the advantage of the involute shape was that it allowed the generation of the correct shape geometrically, without the interference of the human element. Mr. Sharp had mentioned heavy gearing. In this connection, he might say that he had recently seen some teeth developed by an engineering friend, for the latter's own practice, of $\frac{7}{8}$ in. pitch, 20 deg. involute, with an addendum of 0.178 in. Mr. Adamson had been pleased to be able to point out to his friend that the duration of contact in the case of such teeth was covered by Table I. in the paper. Mr. Pitt had put a question relative to the cycloidal and involute forms. As the speaker understood the matter, those were the two theoretically correct shapes, the only usual departure being in the direction of circular arcs, which had been carefully explained by Mr. Sharp. He believed also that the original authority, Willis, used circular arcs to approximate to the correct geometrical shapes; that was subsequently improved upon by Grant, as mentioned in the discussion. The inertia difficulties alluded to by Mr. Pitt were due to errors in the pitch, which were very much greater than the errors in the theoretical shapes. The assumption was that the theoretical shape was right, because it was much easier to measure the error in the pitch than the error in the theoretical shape. Mr. Pitt had also inquired whether, as a fact, the increase of breadth of helical gearing did increase the number of teeth in contact. The speaker believed that this must be so, for the reason that as the width of the pinion was increased the number of teeth in contact would increase, because more of them would engage. Mr. Pitt had mentioned the minimum number of teeth in the pinion for the involute shape; that was suggested by the remark in the paper to the effect that, where a straight-sided rack-tooth was used in order to avoid "interference" the angle of obliquity must be increased to $22\frac{1}{2}$ deg. if a 12-tooth pinion were to be the least of the series. The limit was in the neighbourhood of 12, 13, or 14 teeth. Mr. Sykes had expressed a preference for long teeth as compared with short ones, the explanation of this preference being in the fact that Mr. Sykes was advocating an angle of obliquity much in excess of any suggested in the paper. With an angle of obliquity of $28\frac{1}{2}$ deg. it would be necessary to increase the length of the tooth; otherwise the duration of contact would be too short. The speaker considered that the limitation of the obliquity angle to 20 deg. arose from a desire for a universal system. If only one pair of wheels were to be made, as in turbine reductions, the number of sets of wheels to be made would be limited to a small range, and the angle of obliquity, or any other detail, could be controlled by convenience. But where a universal system was desired, to run from a 12 or 13-tooth pinion up to the rack, a reasonably low angle of obliquity became obligatory. Mr. Sykes had stated that pinions with a small number of teeth would run satisfactorily, and had, in this relation, somewhat misinterpreted Mr. Sharp. The speaker understood Mr. Sharp to have said that the possible error in his (Mr. Sharp's) system of setting up the teeth would vary inversely as the cube of the number of the teeth, so that with Mr. Sharp's system it was an advantage to have a greater number of teeth in the pinion, just as it would be with Mr. Sykes's system. The only objection in the case of Mr. Sykes would lie in the probability that that gentleman used a very high number of revolutions per minute. If a large number of teeth were put in a pinion making a large number of revolutions per minute, a high velocity would result. The speaker was obliged to Mr. Sykes for his reference to the application of flywheels near pinions; this was certainly an improvement on the examples quoted by Lasche about 20 years ago. Further, Mr. Sykes had quoted Grant as stating that odontoidal shapes would be quite as satisfactory as cycloidal or involute shapes. The speaker thought, however, that all that Grant would say would be—just as Mr. Sharp and, years before, Willis had said, and as Mr. Holroyd Smith had indicated—that by the use of the circular arc an approximation could be made to the theoretically correct shape, with which satisfactory results could be obtained. Mr. Sykes had agreed with the speaker as to the ease with which the involute shape could be generated. No doubt the hobbing process mentioned was a great improvement on previous methods, but systems were now being introduced in which the cutters could be ground after hardening, and which employed a straight-sided cutting edge, so that the cutters could be geometrically reproduced with accuracy and ease. It would be interesting to read the published particulars of the new method mentioned by Mr. Sykes. Mr. Adamson believed that there were already in use methods in which the shaping process was employed as he had described, with a straight-sided rack cutter. He did not consider that Mr. Holroyd Smith could claim to be one of the earliest advocates of involute teeth, in view of the reference to Euler's work (dated 1760) in the paper.

The President then announced that Mr. Adamson's paper would be further discussed at a meeting of the Institution in Manchester on Tuesday, the 23rd inst. We subjoin a report of this meeting. The proceedings were brought to a conclusion by the passing of a vote of thanks to the Institution of Civil Engineers for the loan of their lecture-room and for the facilities they had afforded in many other ways during the session.

MEETING AT MANCHESTER.

On the members assembling at 7.30 P.M. in the room of the Engineers' Club, Albert Square, Manchester, Mr. Worthington, the Secretary, announced that Professor Unwin had been unable to come and preside at the meeting. Mr. M. Longridge was at the present time at the Front in France, and other members of the Council who resided in the neighbourhood of Manchester were also not able to attend the meeting. He asked the members present to appoint a chairman, and Principal Garnett, of the Manchester School of Technology, was unanimously voted in the chair.

The chairman, after expressing his thanks for

his selection as chairman of the meeting, stated that the author had carried out a large amount of work on gearing and had also reviewed former work on the same subject and had put this latter in a more convenient form. He (the Chairman) added that British engineers had contributed to the subject principally in the earlier stages, and the information they had contributed was of much value. Mr. Longridge had pointed out twenty-five years ago the damage which resulted from the concentration of the pressure on the end of the teeth and had advocated the reduction of the tooth length, and the author by calling attention to Lasche's work showed how much there was in that done by Mr. Longridge.

The author thanked the Chairman for his remarks and read his paper in abstract.

The discussion was opened by Mr. Alfred Saxon, who said the paper showed evidence of a large amount of work on the part of the author. The title, however, was a little misleading, since it was meant to cover all plain toothed wheels. The author had referred to the introduction of the wheel-moulding machine, followed by the gear-cutting machine, for cycloidal and involute teeth, yet there was still a very large amount of gearing manufactured in cast iron and cast steel from patterns by moulding. The involute form of teeth was used for pitches up to 3 in., and the cycloidal form for pitches above 3 in. For mill drives the cycloidal form gave the best results with the grease lubrication generally used. He (the speaker) mentioned that some years ago he carried out some experiments in the direction put forward by Mr. Longridge, who recommended a 4-in. pitch with a cog 2 in. long. The speaker was understood to say that this was not successful, and now the length of cog was five-eighths the pitch, which did well in practice and was between Brown and Sharpe's and the author's own practice, Brown and Sharpe's being eleven-sixteenths and the author's nine-sixteenths. He (the speaker) added that that referred to cast and machine-cut wheels, and that the author had adopted a good standard. The author had referred to statements made by E. Graves at the Engineers' Club, Philadelphia, but the information should be completed by a statement as to whether the teeth were machine-cut or not. He (the speaker) would also like to know whether the teeth on the New York Subway, also referred to by the author, were cast or cut, also whether the Bolton wheels were cast iron or cast steel; he added he would contribute to the Proceedings by correspondence particulars of a good example of a cast-steel wheel running at a speed of 3000 ft. per minute, with double helical teeth, driving from 1000 to 1250 horse-power. He would also state the number of teeth.

Mr. Joseph Butterworth congratulated the author. He would like, however, to remark that the paper predicated absolute accuracy in every respect; for instance, that the teeth should run in absolute circles, with fixed centres, the shaft being in perfect alignment and perfectly rigid, there being no slackness in the bearings, all of which conditions did not obtain in every-day practice. Want of alignment, to take one point, led to unequal pressure on the teeth. The author had referred to the wear on teeth and had recorded Büchner's statement to the effect that owing to wear involute teeth tended to approximate to cycloidal shapes; instead of one curve there would be two, and the whole matter was upset in regard to accuracy. Even the pressure of the teeth against each other caused deformation, but this must be very small; the slackness in the bearings, however, caused more disturbance. In machine-moulded wheels, the speaker added, they were glad when the error was within one-sixty-fourth in a 3-in. pitch, for a wheel running at a velocity up to 2000 ft. per minute. In mill engines, where the wheels were of large diameter, it was very difficult to obtain them perfectly rigid; they had a certain amount of springiness, and for these and other reasons of every-day practice actual working conditions should be considered as well as the scientific side.

Mr. William G. Gass, with more particular reference to a query by Mr. Saxon, said that a pinion of forged steel with a large wheel of cast steel had been running satisfactorily for three or four years, but owing to the vibrations damaging the foundations, the pitch was reduced. Later Citroen wheels were adopted, and after working for about six months the surface of the steel pinion teeth appeared to wear off in thin flakes, but this did not influence the working. For the majority of gears a finer pitch was better than a coarser, but a fine pitch was not suitable with cast iron; it worked all right with brass, bronze or steel.

Mr. Dempster Smith, who was the next speaker, stated that on account of the difficulty of developing the profiles of the teeth, of the loss due to inaccurate setting and to wearing of the axles and the attendant noise and wear, the cycloidal form of teeth had been almost entirely displaced by the involute. The angle of obliquity commonly adopted for involute gears was 14½ deg., or half the maximum angle of the cycloidal. With involute gears of 14½ deg. obliquity, and an addendum equal to the modulus, or about 0.32 pitch, there would be interference between the rack and all pinions below 30 teeth. The interference might be avoided in several ways, by an increased angle of obliquity, a decreased addendum or by faking the profile. With an angle of obliquity of 22½ deg. and an addendum of ¼ pitch, a 12-tooth pinion would engage with a rack without interference. The increased pressure on the bearings due to the increased angle of action was about 5 per cent. With suitable proportions, the average amount of relative sliding taken over the whole tooth surface was, for involute teeth, probably less than that for cycloidal teeth. Such teeth were much stronger than the ordinary involute or cycloidal teeth, and they retained the advantage of the ordinary involute teeth, in that an alteration in the shaft centres did not impair their smooth running. The Brown and Sharpe form of tooth was approximately an involute tooth with a 14½ deg. angle of obliquity. The tooth was faked so as to avoid interference and under-cutting; it was also claimed to ensure smooth running. The modifications were the outcome of extensive experience and experimenting, but what the modifications were remained the secret of the firm.

Dr. Bowman recommended making the teeth shrouded up to the pitch line; by this means he had increased the speed without any trouble.

Mr. J. Drummond Paton exhibited a small model of a wheel and pinion which he said had resilient teeth whilst being of hard material.

Mr. E. A. Pochin contributed a long statement, which he read, and which will appear in the Institution's Proceedings. He found no difficulty in making a satisfactory metal to drive at 1300 to 1400 ft. per minute, and did not consider powers excessive up to 2000 horse-power.

Mr. V. Gartside agreed with various portions of the paper. He had advocated short teeth for a considerable time; they did away with noise. There seemed to be a certain amount of confusion in regard to cast and to cut gears and he thought they should have been separated. With reference to the shaving off in flakes of the metal forming the teeth, he (the speaker) had had experience of slow-running gears, 3-in. pitch, not hardened, which flaked off. This was owing to the wrong shape of the teeth. It was a slow gear, which made no noise, but an excessive pressure on the teeth caused the abrasion he alluded to. The teeth were filed and cleaned up and the wheels were running still, since he had heard no complaint concerning them for the last seven or eight years. Mr. Dempster Smith had said that the Brown and Sharpe gear was used exclusively in the machine-tool trade; he differed, for gear-cutters and tool-makers used several shapes apart from that of Brown and Sharpe. Hobbing had brought in various methods and his (the speaker's) firm had their special shaped hob, as other firms also had theirs. Railway motor-car makers in the Midlands had advocated a long tooth, but he was not aware of the reason and would like to know whether the teeth were cut, then heat treated, and finished after the heat treatment. This method was followed in France, but he asked whether it was also followed in this country. He (the speaker) was interested in the gears of which a model had been put before the meeting; these were laminated gears and they no doubt acted by dividing the backlash; they put him in mind of driving-wheels which were used for driving a copper-band turning lathe, geared from a variable-speed motor, in which he (the speaker) arranged a pinion having a broad driving portion and a narrow portion which pressed on the back of the teeth. With this arrangement there occurred only a humming noise, which was not displeasing.

Mr. J. P. Bedson found the paper interesting as far as it went; but he had come to learn, and he found the paper did not go far enough. He wanted more information in regard to high speeds, for since the advent of the electric motor and the steam turbine, speed had altered and ideas concerning gearing had altered with it. For a long period he had been running cast-iron gears, machine-moulded, at speeds of 3600 ft. per minute, and they had gone up as high as 6000 ft. per minute. Speeds of 10,000 ft. per minute were being run in turbine-propelled boats, and what was wanted was an appliance which was ready for bringing down these high speeds to commercial speeds. Further investigation was required in the matter of high-speed spur and double helical gearing with a view to showing engineers the maximum speed at which they could be run; and such investigation had a double value in that it was interesting not only to tool-makers, but also to engineers.

In the course of a brief reply to the discussion, Mr. Daniel Adamson said, in regard to Mr. Saxon's remark as to the title of the paper, that it was quite true he had quoted a few examples of bevel teeth; but these were pertinent examples and his intention had been to confine his investigation to straight teeth. Mr. Saxon had also said that cycloidal teeth were more suitable for large pitches; examples which had been referred to showed that the involute shape, 20 deg. obliquity, agreed with the Table I. in the paper, where it would be seen that the involute was suitable for heavy gear. The teeth under Graves' name and those of the New York Subway were, he believed, cut teeth; but he would confirm the point. In reply to Mr. Gass, the pinion referred to was a forged pinion, whilst the wheel was cast. With reference to Mr. Butterworth's remarks, perfection in the mounting of machinery was, of course, very desirable, but there were some departures, which had been provided for in the paper. Mr. Butterworth had said that in some motor-car instances the teeth of the gearing were rounded off; in former times it was usual to assume that teeth might bear at the corner only, in which case the strength increased as the square of the pitch; with machine-cut teeth, where uniform bearing across the whole width could be relied upon, the strength was taken as proportional to the pitch. Mr. Butterworth had also stated that in machine-moulded wheels the error was within $\frac{3}{64}$ and this was a valuable contribution to the discussion. In regard to error, the author added that with cast wheels this was 5 per cent.; 1 per cent. with machine-cut teeth, and 0.1 per cent. with generated wheels, from tooth to tooth. With reference to shrouded teeth, these were of advantage in the age of cast wheels, but the shrouding had been dropped with machine-cut teeth. He (the author) thanked Mr. Drummond Paton for the model he had showed the meeting, but he regretted he could not follow him completely in the matter of lubrication; the point would come out in the written contribution. He (the author) asked Mr. Pochin to send in his opinion concerning his (the author's) diagram, Fig. 16, and concerning the durability factor. The author concluded his remarks by stating that he had endeavoured to establish more rational lines in the matter of gearing, and in regard to Mr. Bedson's remarks he thought accuracy had to be looked to in connection with high speeds and other working conditions, for all of which the same law held good; by increasing accuracy the speed could be increased, the only limit being the one imposed by the centrifugal forces. He hoped some of the members would also add their information to the questions which he had dealt with.

The author was awarded a hearty vote of thanks

for his contribution, and votes of thanks to the Engineers' Club for the accommodation they had afforded to the meeting by the loan of their room, and to the chairman concluded the proceedings.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, May 10, 1916.

THE announcement of a contemplated advance in steel rails of five dollars a ton after next May served to stimulate an extraordinary demand, which for the first four months of the year has aggregated 2,373,800 tons, of which 300,000 tons of the total rail orders were placed last year; the tonnage placed during April was 955,400 tons. Numerous inquiries for rails are now in the market, and no doubt a large volume of business will be placed at an early day. The pig-iron production for the past month has dropped off as much as 150,000 tons, owing to the blowing out of many furnaces for repairing purposes; all furnaces are working at high pressure and some new furnaces are being blown in. Prices remain high and firm. Generally speaking, the market is rather quiet. A large volume of business is in sight for railroad spikes for delivery next year, amounting to 100,000 kegs. The general drift in prices is in an upward direction. Numerous recent orders for plates were placed subject to the option of manufacturers as to deliveries. Steel bars are also very active, or would be if the mills could accept the proffered business. Numerous orders for structural steel have appeared since the writing of the last report; much of this demand is for new industrial plants and extensions of existing plants. The new Sun Shipbuilding Company, near Philadelphia, are waiting for initial business on 6000 tons of shapes, and the Midvale concern in this city is anxiously awaiting the delivery of 3500 tons of material for shop extension. The Italian Government is negotiating for a large quantity of shell bars, and other European Governments are also urgently endeavouring to secure deliveries of munition material for the latter half of the year. An expansion of steel-making capacity was begun a year ago and some of that capacity is now ready for engagement. The American Bridge Company will soon begin deliveries of 28,000 tons of structural steel for an extension of elevated railway work in New York city, and the Pennsylvania Company, which has arranged for 15,000 tons of steel, have their order in.

MR. JAMES C. ECKLIFF.—We regret to announce the death on May 9 of Mr. James C. Eckliff, President of the Eckliff Automatic Boiler Circulator Company, of Detroit, U.S.A.

BRITISH STANDARD NOMENCLATURE OF TARS, PITCHES, BITUMENS AND ASPHALTS.—The great use of tar and bitumen in road-making has rendered it necessary that the qualities should be sharply defined, so that engineers may know exactly what to specify, and manufacturers may realise what is expected. The Engineering Standards Committee therefore appointed a sectional committee on road material on July 18, 1912. A subcommittee to deal with bituminous materials was appointed in 1913, and has now reported. They divide the materials into (1) tars and pitches obtained by the destructive distillation of coal and other similar substances; (2) bitumens and asphalts which are found in nature, or are obtained artificially from asphaltic oils; chemical binders, such as cements (these latter are not dealt with in the report). Tar is defined as the volatile products of the destructive distillation of hydrocarbon matter; pitch is the solid or semi-solid residue from the partial evaporation of tar; bitumen is the generic term for a group of hydro-carbon products soluble in carbon disulphide, which either occur in nature or are obtained by the evaporation of asphaltic oils; asphalt is a mixture of bitumen and finely-graded mineral matter. Standard specifications are given for No. 1 tar, No. 2 tar, and pitch. The report can be obtained from the Committee at 28, Victoria-street, Westminster, or from Messrs. Crosby Lockwood and Son, 7, Stationers' Hall Court, E.C., at the price of 5s. net.

QUEENSLAND MINING INDUSTRY IN 1915.—The annual report of the Under-Secretary for Mines, on the Queensland mining industry for the year 1915, states that the value of last year's mineral output was 3,324,861*l.*, an increase, when compared with that of the preceding year, of 348,581*l.* All the principal goldfields of the State, except Mount Morgan, which produced more value in copper than in gold, showed declining yields. The value of the copper production of the State alone was considerably greater than that of gold, while the aggregate value of all "other minerals" was more than double that of the metal the recovery of which for many years constituted almost the only mining in the State. The prices fixed by the Imperial Government for wolfram and molybdenite have had a very stimulating effect in the centres where they are found, and great activity has been displayed throughout the year in the search for, and the obtaining of, these minerals at very numerous places in the Herberton and Chillagoe mineral fields. At the beginning of 1915 the price of wolfram in London was under 100*l.* per ton, but later it rose to nearly 200*l.* per ton. This proved to be a fortunate rise at a very opportune time, for when, early in September, the Imperial Government fixed for twelve months a standard price for wolfram, it did so at the gratifying figure of 192*l.* 10*s.* per ton, for 70 per cent. tungstic acid, while at the same time making that for molybdenite 525*l.* per ton. This standard quotation has given to the wolfram miner a feeling of stability and security never before enjoyed in all his dealings with that much-buffeted mineral, which is more widely distributed throughout the far northern portion of Queensland than any other.

ELECTRIFICATION OF SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

WE are indebted to Messrs. Merz and McLellan, consulting electrical engineers to the North-Eastern Railway, for the following account of the electrification of the Shildon-Newport branch of that line.

The North-Eastern Railway Company was one of the first main line British Railway Companies to adopt electric traction, having as far back as 1904, when Sir George Gibb was General Manager, successfully applied electrical operation to their Newcastle and Tyneside suburban traffic. Once more this Company has acted as a pioneer of electric traction in applying it to heavy freight haulage.

In 1911 the General Manager, Sir A. Kaye Butterworth, instructed their consulting Electrical Engineers, Messrs. Merz and McLellan, to report generally on the question of electrification, with reference to the special conditions of the North Eastern System, and following the visit of their Chief Mechanical Engineer, Mr. Vincent Raven, with Mr. Merz to the United States in 1911, the directors decided to proceed at once with a preliminary scheme.

Electric working was started on July 1, 1915, on the Shildon-Newport Line, a limited service being run in the first instance, as the overhead track was not then completed. The service was gradually extended until, in 1916, the full service was in operation.

The Shildon-Newport Route was selected for trial, this being an important freight line dealing almost exclusively with heavy mineral traffic. Some historical interest attaches to this selection, since the track runs over a portion of the original Stockton to Darlington Railway, the first public railway on which steam locomotives were used for conveying passengers and goods.* The fact that the first trial of heavy freight electric haulage on a large scale in England should be carried out on this particular route is noteworthy.

Beyond the usual considerations affecting the decision to apply electric traction to such a line, there was a special factor which differentiated the North-Eastern Railway lines from others in the United Kingdom. As is well known, the production and distribution of electric power has been developed upon a larger scale on the North-East Coast than in any other part of this country, and a large proportion of the power is derived from electric generating stations using as fuel the waste heat and gases derived from coke ovens and blast furnaces in the Durham and the Cleveland districts. An ample supply of cheap electrical energy was therefore available from the systems of the existing power companies, and this fact, obviating as it does the necessity for a large capital expenditure by the railway company on power station plant, had an important bearing on the whole scheme.

General Description.—The electrified line described hereafter has a route length of between 18 and 19 miles, and connects the mineral sidings at Shildon, which form one of the largest marshalling yards in Great Britain, with the Erimus Sidings at Newport, near Middlesbrough. A considerable portion of the sidings at both ends is also electrified, so that, including the sidings, about 50 miles of single track are equipped for electric working.

Fig. 1, subjoined, shows the general route electrified, and Fig. 2 the gradients. The general gradient is in favour of the laden traffic, the steepest gradient being 1 in 103. The line carries the heavy mineral traffic from

Fig. 1

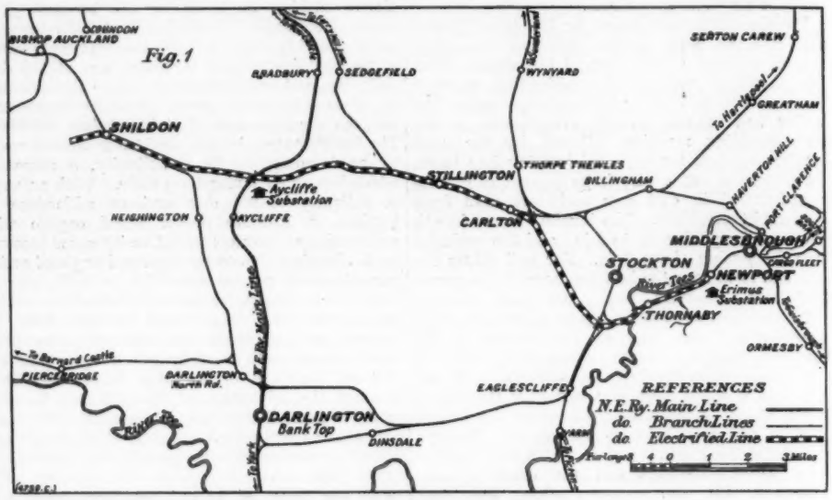
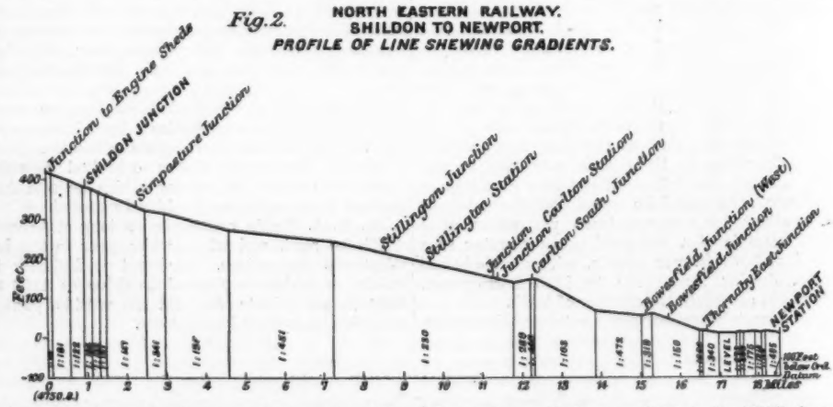


Fig. 2. NORTH EASTERN RAILWAY. SHILDON TO NEWPORT. PROFILE OF LINE SHEWING GRADIENTS.



* This line was opened in 1825, and two of the original locomotives designed by George Stephenson are to this day preserved in the Darlington Station of the N.E.R.

Overhead Track Equipment.—It was decided to adopt the high-tension direct-current system, current being supplied to the locomotives through overhead contact wires, at a pressure of 1500 volts, from the two rotary-converter sub-stations described later. The overhead track equipment was carried out under the supervision of the Railway Company's then Chief Engineer, Mr. C. A. Harrison.

Figs. 3 to 8, page 497, show the general type of catenary construction adopted. The overhead contact wires on the main portions of the track consist of two hard-drawn copper conductors, each 0.155-sq. in. section, but on certain portions of the sidings, where the loads are not so heavy, a single contact wire only is used. The wires are supported by a solid steel auxiliary catenary wire, to which they are attached by sliding clips. This auxiliary catenary is in turn suspended from the main stranded steel catenary by means of steel wire droppers. The main steel catenary wire is supported from the steel structures, shown in several of the accompanying photographs, by means of special insulators, double insulation being used throughout. The normal span between the steel structures is 110 yards, but on curves and sidings they are placed at lesser intervals, depending on the conditions existing. The normal height of the contact wire from rail level is 16 ft. 6 in., but at level crossings this is increased to 18 ft. 6 in., and under some of the low bridges, of which there are a large number on this route, the height from the rail level is reduced, the

THE ELECTRIFICATION OF THE SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

MESSRS. MERZ AND McLELLAN, MM. INST. C.E., LONDON, ENGINEERS.

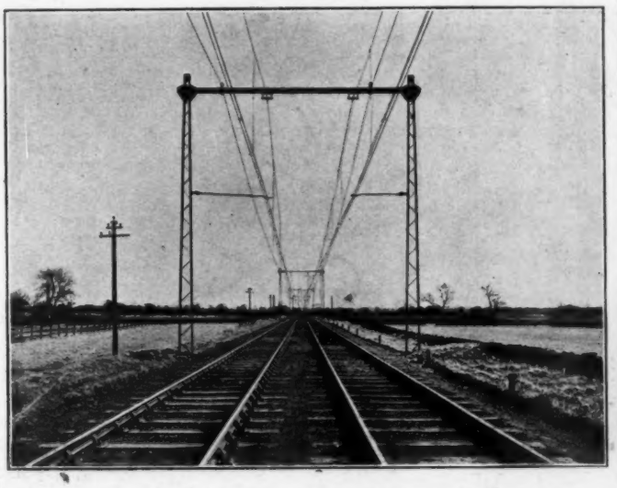


FIG 3. END VIEW OF OVERHEAD EQUIPMENT.

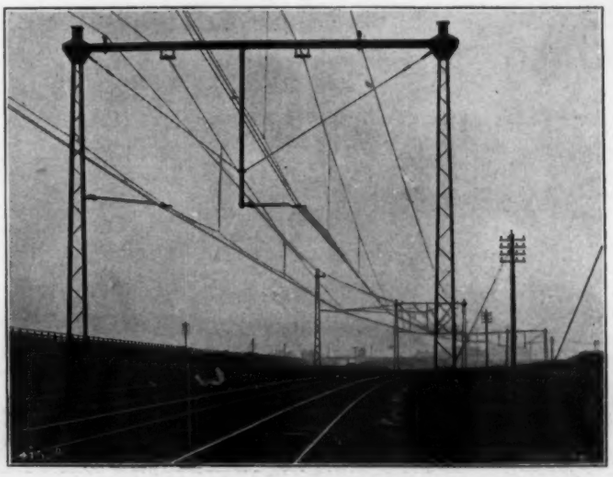


FIG. 4. CURVE AT BOWESFIELD JUNCTION.

FIG. 5. CANTILEVER CONSTRUCTION FOR SINGLE TRACK.

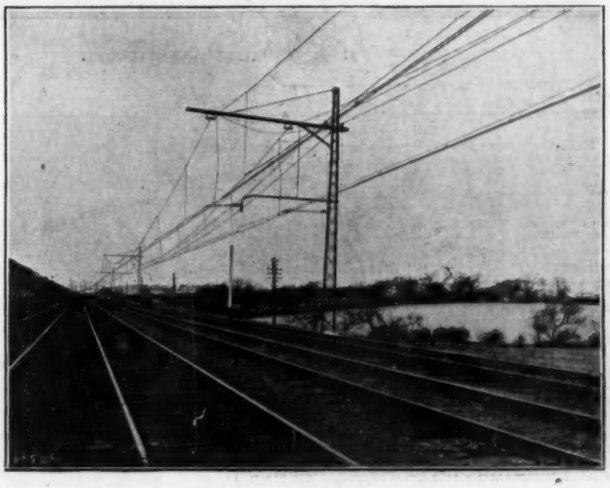


FIG. 6. CANTILEVER CONSTRUCTION FOR TWO TRACKS.

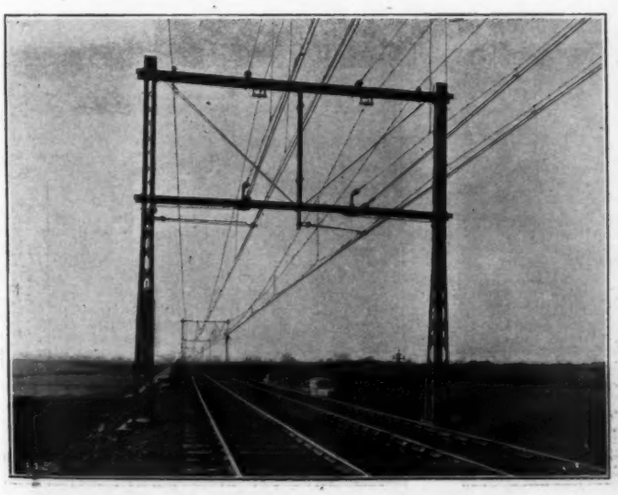


FIG. 7. TYPICAL TENSIONING STRUCTURE.

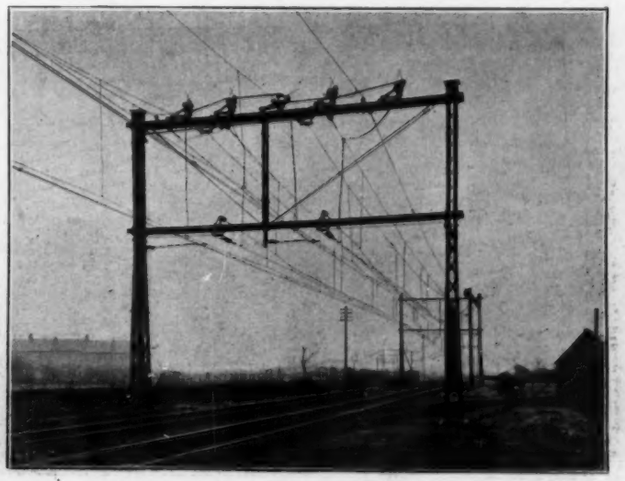


FIG. 8. GENERAL VIEW OF SECTION SWITCHES.

THE ELECTRIFICATION OF THE SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

MESSRS. MERZ AND McLELLAN, MM. INST. C.E., LONDON, ENGINEERS.

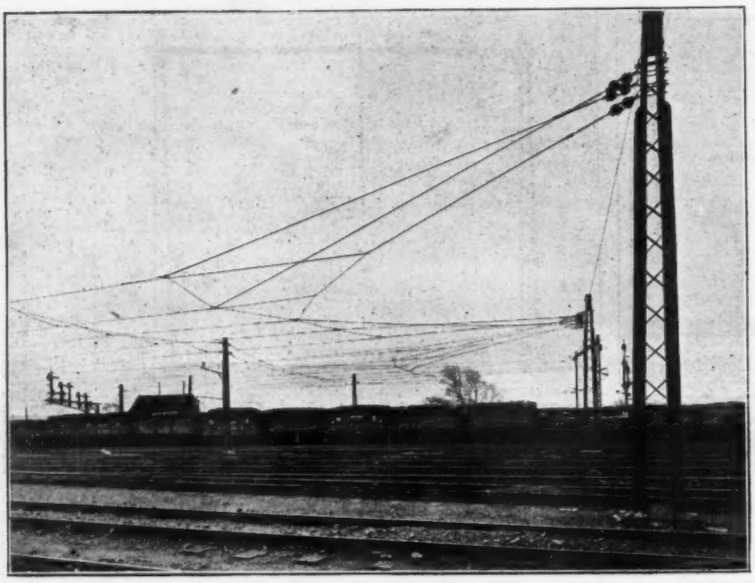


Fig. 9. Terminal Arrangement.

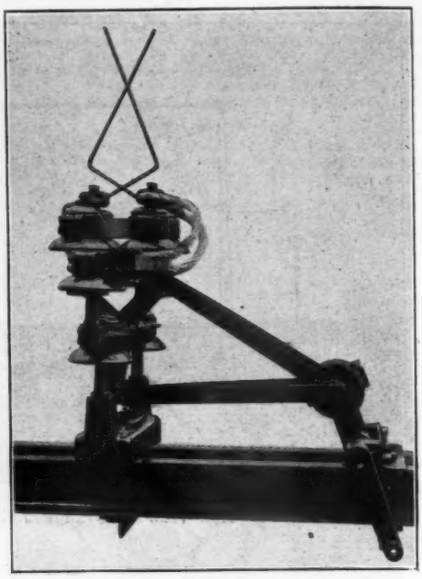


Fig. 11. Details of Section Switch.

Fig. 10. Seven-Track Span Wire Construction.

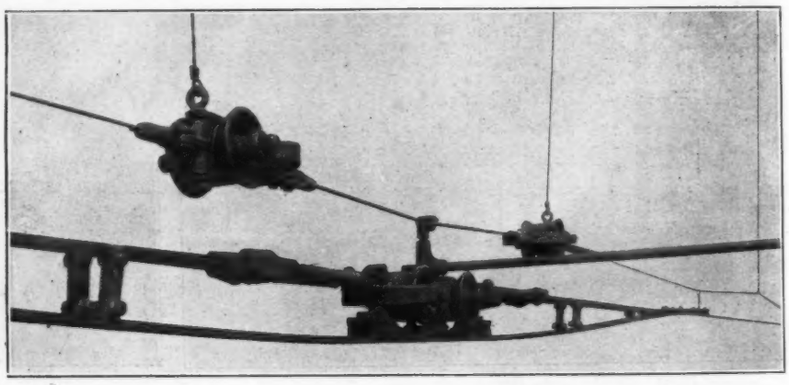


Fig. 12. Detail of Section Insulator.

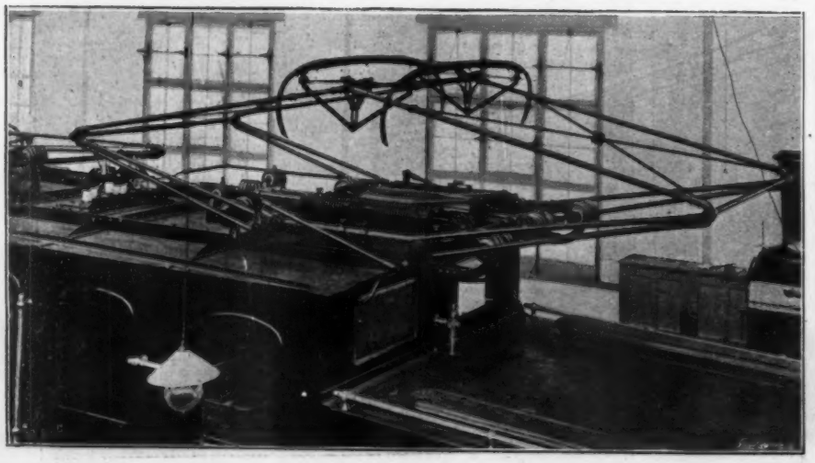


Fig. 13. Side View of Bows.

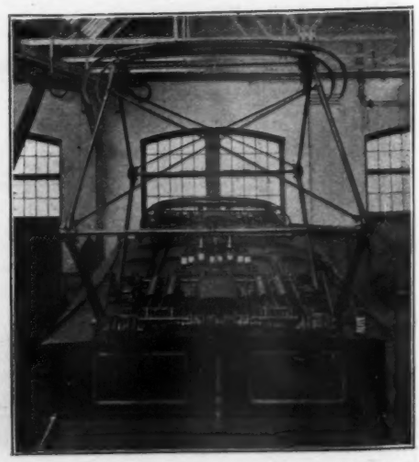


Fig. 14. End View of Roof of Cab.

THE ELECTRIFICATION OF THE SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

MESSRS. MERZ AND McLELLAN, MM. INST. C.E., LONDON, ENGINEERS.

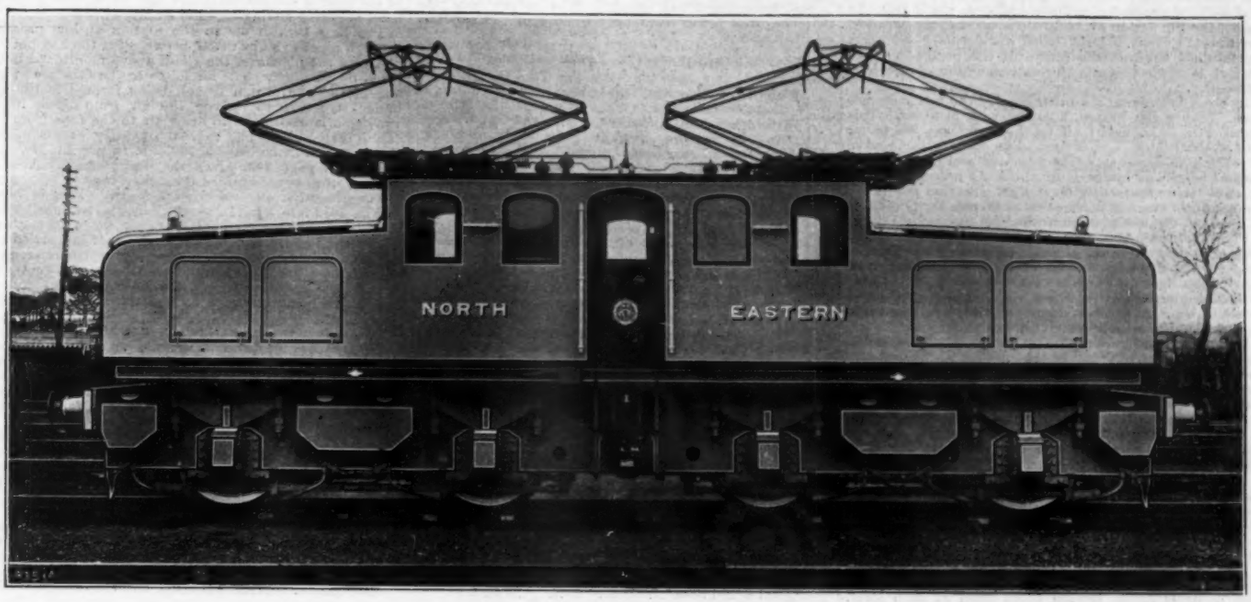


FIG. 15. HEAVY FREIGHT LOCOMOTIVE.

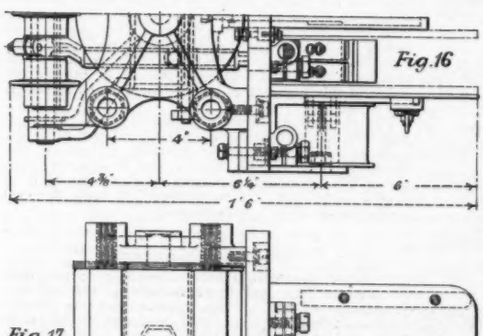


Fig. 16.

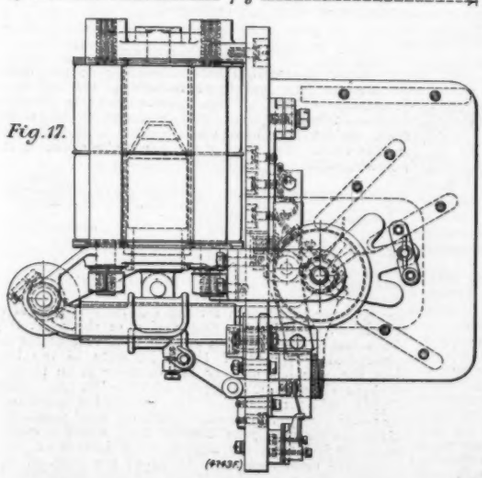


Fig. 17.

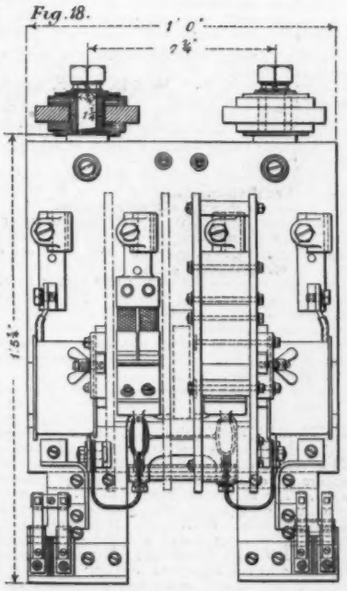


Fig. 18.

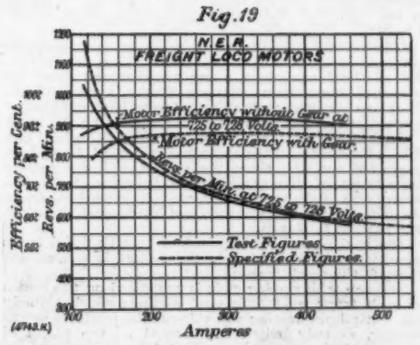


Fig. 19.

minimum height being about 13 ft. 8 in. Two auxiliary stranded copper feeder wires, each of 0.194 sq. in. section, are carried on the top of the steel structures referred to, and are connected in parallel with the main contact wires at frequent intervals. The purpose of these feeder wires is to increase the conductivity of the overhead equipment.

Each steel structure carries a pair of insulated steadying-arms, well shown in Figs. 3 to 8, page 497. These steadying-arms are pivoted in all directions, and are attached to the contact wires by means of clips, their purpose being to fix the position of the contact wire relatively to the track. The contact wires are staggered in the usual way to prevent undue wear of the bow collectors.

The general type of steel structure carrying the wires over straight parts of the track can be seen in Fig. 3. It consists of two steel masts and a cross-girder, each of these being made up of two channels with flat steel bracing. On curves a centre strut, steadied by steel tie-rods, is added (see Fig. 4), the steadying-arm on the mast on the inside of the curve being removed and fixed to the centre strut mentioned, so as to ensure the steadying-arm being always in tension.

Independent pull-off masts are fitted on sharp curves where necessary.

In Fig. 6 an arrangement is shown of a two-track structure, where it was impossible to erect two masts. Cantilever construction is here adopted, the general features of which can be seen from the figure.

Fig. 5 shows similar cantilever construction over a single track. In this case, it will be noted that wood poles were used, a short length of single track being equipped in this way for experimental purposes. All steel structures carrying the overhead track equipment are bonded to the running rails by means of a hard copper bond of No. 0.08 sq. in. section. Any steel structures carrying signals which are in proximity to the electrical equipment are also similarly bonded to the running rails.

In order to limit as far as possible the sag of the contact wires due to temperature variation, automatic tensioning was adopted. The tensioning points are approximately 1100 yards apart.

Fig. 7 shows a typical tensioning structure. Two of these structures are placed 65 yards apart at the end of each tension length, the wires from the opposite lengths overlapping by this amount. The end of each contact wire is raised at the tensioning structure to which it is fixed to a height of about 18 in. clear of the normal level at that point, so that the locomotive bows ride gently and without shock from one tensioning length on to the next. The contact wires are anchored to the auxiliary catenary wire at a point two-thirds of the distance along each tensioning length in the running direction.

The tensioning structures consist of strong steel masts made up of four angle-irons, with angle-iron bracing, and it will be seen from the figure that the structures are fitted with two cross-girders with a centre strut. The tensioning weights are slung in the centre of the mast structure by chains passing over pulleys attached to the contact wire. A normal tension of about 1 ton is maintained by this means in the double contact wire. The auxiliary catenary wire is in all cases anchored off to the lower girder of the tensioning structure, but the main catenary is continuous except at tensioning points, at which section switches are fitted. At the latter points the main catenary is also anchored off, but to the top girder. On some of the sidings where only shunting work is done, and the loads on the locomotives are not heavy, a single contact wire is used over each track, with ordinary tramway span wire construction. An example is shown in Fig. 10, page 498, where such a construction spanning seven tracks can be seen. On some of the marshalling and reception sidings, which are not equipped throughout, and on which it is only necessary for the overhead construction to permit of the locomotives entering to pick up their load, the wires are terminated as shown in Fig. 9. Danger-boards are fitted, beyond which electric locomotives should not pass; but if by any chance they should over-run

these, the terminal construction is such that no damage would be done to the bow collectors or to the overhead track.

There are a large number of low stone bridges on this route. At some of these bridges it is possible to carry the main catenary wire through the bridge, but at most of them it is necessary to anchor it off to the bridge. In these cases, in order to obtain the necessary clearance, the contact wires, together with the auxiliary catenary, are brought towards the centre of the bridge, so that contact is made towards the extreme edge of the bow collector.

In order to prevent the other edge of the bow collector from striking the bridge, a guard wire is fitted. This guard wire is anchored off to the structures on either side of the bridge, and is only alive while a locomotive is passing underneath. The track is sectioned on the normal length at intervals of about 2½ miles, and considerably more frequently on sidings. Section points are arranged, to occur in most cases at tensioning points, so as to avoid the use of section insulators.

Fig. 11 shows the type of section switch adopted. These switches are fitted in the open, so that it is permissible to use the horn break arrangement which can be seen in the figure. They are erected on the uppermost cross-girder of the section structures, and are operated by levers in the signal cabin, to which they are connected by the usual arrangement of railway point rods.

Fig. 8, page 497, shows a view of five section switches fitted on a girder. Normally the tracks are coupled in parallel, but by means of the section switches the up and down tracks can be operated separately if desired. As the train control system of working is in use on this route, the signal cabins are connected by telephone with a central control office situated at Newport, and the handling of these switches is directed from the same point.

In certain positions, such as at crossovers and some of the sidings, where it was impossible to avoid their use, section insulators are fitted. This type of insulator is shown in Fig. 12, page 498. In all cases, however, these are fitted at points where the locomotives are travelling at low speed.

The track rails are bonded at the joints with stranded copper bonds fitted under the fish plates, two bonds each of 0.109 sq.-in. section being fixed at each joint. They are also cross-bonded between the two rails at intervals of 300 ft., and between the two inner rails of adjacent tracks at the same space interval, the bonds in the 6-ft. way being midway between those in the 4-ft. way.

Locomotives.—The freight locomotives were designed and built at the N.E.R. locomotive works at Darlington, the electrical equipment being supplied and fitted by Messrs. Siemens Bros. Dynamo Works, Ltd., Stafford. They are designed to haul trains weighing 1400 tons at a speed of not less than 25 miles per hour on the level.

Figs. 21 and 22, Plate XLIV., and Figs. 23 to 26, Plate XLV., together with the photographs Figs. 13, 14, and 15, pages 498 and 499, show the details and the general appearance of the engines, and below is a detailed description of the same. The work was carried out under the direct supervision of the Chief Mechanical Engineer, Mr. Vincent L. Raven.

The engine may be described as an articulated truck locomotive, in which the tractive effort is transmitted through the truck frames.

The cab with sloping ends is supported on the centre of each truck by strong steel castings which embody the central-pin bearing and side-rubbing surfaces in one casting, securely bolted and riveted to the plates of the cab platform, which consists of four beams secured to plates at the top and bottom. The transome between the truck frames at the centre is built up of plates and angles securely riveted to the side frames of the truck. On the centre of the transome is a steel casting with which the centre bearing mentioned above engages. Rubbing pieces are fitted at each side, which bear on the rubbing surfaces on the casting mentioned. The centre pin at No. 1 end is a good working fit in its bearings on the centre of the transome. At No. 2 end provision is made for the creeping up of the trucks when passing round curves, but no allowance for movement transversely. The buffers are carried directly on the truck frames. The trucks are connected by means of a buffer coupling and arranged for lateral movement with vertical rigidity: the coupling is made with a slotted hole for a drawbar to pass through. The trucks are then securely held together by means of a drawbar and spring, which can be adjusted (the compression of spring being ¾ in. per 7 tons load) to act as a connection between the two trucks. This spring cannot be subjected to heavy compression, resulting from buffing action, as the buffer part of the coupling between trucks receives the buffing stresses directly through the truck frames without subjecting the centre pins and platform to any stress other than those required to carry the weight of the cab apparatus on them.

The sloping ends are partitioned off from the cab and contain the resistances, contactors, motor cut-out switches multiple cut-out switches and all high-tension electrical apparatus. Entrance to each sloping end can be obtained through doors which are normally locked.

The bow collectors on the roof of the cab (see Figs. 13 and 14, page 498) are raised and maintained in connection with the contact wire by compressed air. A cock is fitted on the air system, the removable handle of which forms the key of the doors mentioned. This handle is so arranged that it can only be removed when the cock is in the exhaust position, so that it is impossible to open the doors of the sloping ends while the bows are in contact with the overhead wire.

In the cab two master controllers are fitted, one at each end. The cab also contains all auxiliary switches for controlling the air compressor and the two dynamotors described later, and for lighting and heating. It also contains the control valves for the Westinghouse brake and for air sanding. In the centre of the cab there is a vertical hand-wheel for the hand-brake (see Fig. 24, Plate XLV.).

The dynamotors are securely fixed to the floor, the switches, &c., being fixed on the sides of the cab and weather boards.

DIMENSIONS AND PARTICULARS.

	Tons	Ct.	Qr.	Lb.
Weight of electrical equipment, inclusive of motors	24	5	0	0
Ditto of mechanical parts	50	3	0	0
Ditto of motors without gear wheels and gear cases	3	3	0	0
Ditto ditto with gear cases and gear wheels	3	13	0	24
Total weight of mechanical and electrical apparatus	74	8	0	0
Approximate height of centre of gravity	4 ft. 6 in.			
Main dimensions of motors:				
Axial length over windings	24 $\frac{5}{16}$ in.			
Ditto ditto over core	11 $\frac{1}{2}$ in.			
Ditto diameter of armature	21 $\frac{1}{2}$ in.			
Ditto diameter of commutators	18 $\frac{7}{16}$ in.			
Ditto length of commutator	7 $\frac{1}{2}$ in.			
Ditto number of segments	195			
Ditto air gap	$\frac{1}{16}$ in.			

Speed of motors at normal locomotive speed of 25 miles per hour, 787 revolutions per minute.

LEADING DIMENSIONS OF MECHANICAL PARTS.

Length over buffers	39 ft. 4 in.
Height from rail to centre of buffers	3 ft. 5 in.
Height of cab roof from rail	11 ft. 6½ in.
Height of trolley wearing strip from rail when down	13 ft. 1 $\frac{5}{16}$ in.
Width of trolley wearing strip over horn ends	5 ft. 10 $\frac{7}{8}$ in.
Width of cab	7 ft. 6 $\frac{1}{4}$ in.
Width over footplate	8 ft. 4 in.
Total wheel base	27 ft. 0 in.
Wheel base of each truck	8 ft. 9 in.
Centres of trucks	18 ft. 3 in.
Diameter of wheels	4 ft. 0 in.
Diameter of wheel seat on axle	8 $\frac{1}{2}$ in. by 7 $\frac{1}{8}$ in. long
Size of axle at spur-wheel seat	8 $\frac{5}{16}$ in. by 5 $\frac{1}{4}$ in. long
Diameter of journals	6 $\frac{3}{4}$ in. by 13 in.
Motor suspension bearings on axle	7 $\frac{7}{8}$ in. by 13 $\frac{1}{16}$ in.
Springs—laminated	3 ft. 6 in. span, 18 plts., 4 in. by $\frac{1}{4}$ in.

Cab and sloping ends constructed of steel channels, plates and angles.

Under structure, 8-in. by 6-in. beams, 8-in. by 3½-in. channels, and ¼-in. plates.

Trucks, articulated.

Truck frames—steel plates, 1¼ in. thick.

Truck drag plates—flanged plates riveted up securely to frame plates.

Truck transome—built of plates and angles (steel), cast-steel centrepiece fitted on centre to receive centre-pin on under-structure, also side bearers.

The motor equipment of each locomotive consists of four totally enclosed motors each driving an axle through single reduction twin gearing. The gears are machine-cut with straight teeth of the involute pattern, the face dimensions of the spur wheels and pinion being 3 $\frac{1}{16}$ in. A pinion is mounted on each end of the armature shaft and meshes into a corresponding gear wheel, mounted on the running wheel axle, the gear ratio being 1 to 4.5. Sections through the motor and gears are reproduced in Figs. 27 to 31, page 502. In Fig. 27 the running wheels are shown dotted.

The motors are suspended by means of a cross beam suspension bar with bearings and reaction springs. These, with the motor suspension bearings on the axle, provide the motors with four points of suspension.

The four main motors are fitted two in each bogie and are each wound for 750 volts, the pair of motors in each bogie being connected permanently in series. The four main motors of each locomotive thus form two units, which are controlled on the usual series parallel system. Each motor is capable of developing 275 brake horse-power at a speed of 20 miles for one hour with forced ventilation. The motor equipment is capable without injury of exerting a torque sufficient to skid the wheels under any conditions of rail, and will exert an average pull of 28,000 lb. at the tread of the wheels when starting under normal conditions of rail. The maximum pull at the tread of the wheels is, of course, considerably greater than this.

The motors and gearing are designed so as to run at a speed of 45 miles per hour without exceeding the limits of safety, but the normal speed on the level when hauling a train of 1400 British tons is 25 miles per hour. The equipment is so designed that each locomotive is capable of performing four round trips in 12 hours, each consisting of a trip from Shildon to Newport with a train of 1400 tons, followed by a trip from Newport to Shildon with a train of 800 tons, the distance of each trip being about 18 miles. The locomotives are able to start a train of 800 tons from rest on a grade of 1 in 100 and accelerate to normal running speed.

A novel feature is the ring lubrication on the motor shaft. This can be seen in Fig. 28, page 502. The gearing is enclosed in a welded sheet-iron case fitted with a siphon-wick oil lubricator.

Sight doors are fitted on the gear-case so that the condition of the gears can be regularly examined. The air-supply for ventilating the motors is supplied from fans driven by the dynamotors, which are described later, but a special feature is shown in Fig. 31. In order to avoid the use of a flexible pipe between the fan air-duct in the base of the cab structure and the motors a special form of spring sliding-gland is employed.

The fans furnish air to the motors at low pressure through pipes to a box fitted between the top and bottom plates of the platform, the gland above mentioned being fitted on this box. The air inlets to the fans are at the end of the platform, a trough being formed in the cab under-structure to convey the air from these inlets. Provision is also made to draw air to the fans from the cab if necessary. The normal quantity of air passed through each motor case is 700 cub. ft. per minute.

Fig. 19, page 499, gives the performance curves of these motors as ascertained from shop tests.

The general arrangement of the control wiring is shown in Fig. 20, Plate XLIII., to which is also attached a key diagram. Two master controllers are fitted in the cab, one at each end. Notching up can either be carried out by hand or automatically. The automatic arrangement consists of a spring which is wound up by the controller handle, the speed at which the controller drum follows the handle being governed by a step-by-step escapement movement.

The maximum current taken at each step is limited by a limit switch fitted in the sloping ends of the cab, which on the current rising beyond a predetermined limit, closes the circuit of a small magnetic interlock, which locks the escapement mentioned, holding the drum of the controller until the current has fallen to the required value.

In addition to the above, by means of a catch inside the controller, which, when lifted, disconnects the spring and escapement action, the automatic arrangement described can be thrown out of action and notching performed by hand.

An acceleration switch is also provided so that in special circumstances the adjustment limit switch mentioned can be altered by cutting out some of the turns of the coil, thus allowing of a larger current for accelerating under special conditions.

Each master controller is fitted with the usual reversing barrel, the handle of which can only be removed when in the "off" position. When left in this position, the reversing handle locks the main handle. There is also fitted on the master controller a small spring switch by means of which the automatic circuit breaker on the locomotive can be tripped or set. This switch is also locked by the reversing handle in the "off" position.

Current for operating the whole of the control circuits and the lighting and heating in the cab is supplied from either of the dynamotors at a pressure equal to half the line voltage.

The contactors shown in detail in Figs. 16 to 18, page 499, are electrically operated, and are also fitted with auxiliary interlocking contacts to ensure their operating in the correct order. The resistances, which are of the usual cast-iron grid type, are fitted in the sloping ends, but are partitioned off from the other apparatus in these compartments.

(To be continued.)

GERMAN ROLLING-MILLS.—According to the Union of German Iron and Steel Industries, the aggregate production of the rolling mills within the German Customs' Union during 1915 amounted to 11,243,360 tons, against 13,165,589 tons in 1914, and 16,698,950 tons in 1913. The effect of the war is also shown in the following table:—

	Tons.
January to July, 1914	9,700,389
,, ,, 1915	6,329,657
August to December, 1914	3,465,200
,, ,, 1915	4,913,700

The average production per month for the seven months of peace in 1914 consequently amounted to 1,385,770 tons, against 904,237 tons for the period 1915, or about 65 per cent. of the peace production. On the other hand, the monthly production for the five months August to December, in 1914, the first period of the year, only amounted to 693,040 tons, against 982,741 tons for the corresponding period of 1915. In spite of the long time the war has already lasted, there is an increase of about 42 per cent. compared with the last five months of 1914, and a production of 71 per cent. of the corresponding peace average. Compared with the total production of the last complete year of peace, 1913, which amounted to 16,698,950 tons, the aggregate production of 1915, 11,243,360 tons, represents about 67 per cent. of the former. The production of the different specialities in the two years will appear from the subjoined table:—

	1913. Tons.	1915. Tons.	Per Cent. of Peace Production.
Half-finished products intended for sale	2,709,990	1,641,951	59
Railway material	2,470,065	1,424,548	58
Girders	1,555,511	766,653	49
Bar iron	4,429,558	3,328,685	75
Hoop iron	395,602	265,139	67
Rolled wire	1,157,873	750,934	65
Heavy plates	1,408,591	966,898	69
Thin plates	990,046	698,695	71
Tinned plates	83,051	92,751	112
Tubes	750,084	460,765	61
Rolling stock	374,062	192,080	51
Hammered iron	207,602	236,680	114
Other finished products	176,895	487,581	276

The production of steel during the first quarter of the current year exceeds that of the corresponding period for 1915 by about 800,000 tons.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—During the closing day of last week the Glasgow pig-iron warrant market remained in the same lifeless condition as has characterised it more or less since the recent Order in Council prohibiting speculation in metals came into force. There was practically no movement, and it is problematic if any stock changed hands. On Wednesday, Thursday and Friday buyers continued to quote 90s. per ton, but sellers were conspicuous by their absence. Nor was this improved upon when the market re-opened on Monday, while on Tuesday, with the market being closed for the local King's Birthday holiday, no business, of course, was transacted.

Scotch Steel Trade.—Despite the activity in every branch of the iron and steel trade throughout the West of Scotland, actual news is scarce, for without doubt war work of one kind or another absorbs the entire attention of manufacturers, and conditions are abnormal, so much so that practically no ordinary mercantile business whatever can be undertaken by any of the local steel works. There is little prospect of these conditions being in any way improved for some considerable time. The enormous pressure for delivery continues unabated, and shell bars, light sheets, and a variety of light sections are much in request. Much anxiety still prevails with regard to the recent Order in Council, which, in one way, is having disastrous effect upon the overseas trade generally, both colonial and foreign; for although much additional material is now available for the home market, where it certainly is greatly needed, our manufacturers cannot afford completely to disregard the claims of their export customers. Prices are still strong, angles being quoted 14*l.* per ton, or thereabouts; ship-plates, 13*l.* 15s. and up; and boiler plates 14*l.* 10s. per ton and up; all less the usual 2½ per cent. discount.

Malleable-Iron Trade.—The firm position occupied for some time now by the malleable-iron makers remains unchanged, for not only are orders plentiful and obtained without the least trouble, but the maximum amount of work is being undertaken, and put through with great briskness. Even with "Crown" bars at 14*l.* to 14*l.* 2s. 6d. per ton f.o.b. Glasgow, full extras are demanded in every case, a feature which differs remarkably from pre-war days.

Scotch Pig-Iron Trade.—Business in the Scotch pig-iron trade continues remarkably good, makers being actively employed. Indeed, in quite a number of cases they are having to draw upon their stocks, owing to the extreme difficulty of keeping their output on a level with the excessive demand. In regard to hematite, things are much similar, and, even with many of the producing furnaces being transferred from the production of ordinary foundry iron to that of hematite, in not a few instances the supply is running short of the demand. Consequently there is a decided scarcity of ordinary foundry and No. 1 quality iron. Certainly the demand for foundry sorts, especially for the export trade, is rather slower than usual at the moment. Without doubt the licensing question is having a most decided effect on all overseas trade. There has been no change in price of makers' (No. 1) iron during the week, the quotations still remaining as follow:—Clyde, Calder, Summerlee and Langloan, 130s. per ton; Gartsherrie, 131s. 6d (all shipped at Glasgow); Eglinton, 126s. 6d., Glengarnock, 130s. (both at Ardrossan); Dalmellington, 126s. 6d. (at Ayr); Shotts and Carron, 130s. (both at Leith).

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—The market is stiffening all round with the approach of the season for the fixing up of contracts for all classes of customers. Gas companies are having a particularly trying time owing to the fact that colliery companies are not in present circumstances so dependent upon this class of contract for much of their output, as in pre-war times. It is anticipated that none of the contracts, no matter what quality of fuel is required, will be let at anything other than a considerable rise in price upon what has been paid during the past twelve months. Shipments are still on a considerable scale, with almost any price paid in cases where the delivery is prompt. Nearly all the export tonnage is ear-marked for French, Italian, and Russian destinations. Over 30s. per ton at pit is paid for best-grade South Yorkshire hards for export purposes. The prices for inland business remain at the maximum. The house coal demand has considerably fallen off, but gas companies are swallowing up any surplus that collieries may possess in this direction. The steam-coal market experiences a very active inquiry. Hards, cobbles, nuts and slacks are sold in enormous quantities, for works are trying to increase floating stocks, but are only indifferently successful. Quotations:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best silkstones, 18s. 6d. to 19s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house coal, 16s. to 17s.; best large nuts, 15s. 6d. to 16s. 6d.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 12s. to 13s.; seconds, 11s. to 12s.; smalls, 8s. to 9s.

Iron and Steel.—The question of hematites is again to the fore. The Sheffield consumption is placed at an enormous figure, and is on an increasing scale, which gives rise to the prediction that there may be a famine in the near future, for it is pointed out the labour shortage almost inevitably rules out any possibility of an extension of production. One satisfactory feature is the admirable manner in which the Government have answered in respect to prices in the home market trade. Some little time ago the Government had to come forward with their promised subsidies to makers because of the abnormal freights and the high prices of Spanish ore. This kept the home market quotations within the prescribed figure. The latest development is the drop in the scale of freights from 30s. to 20s., and also an arrangement whereby the necessary tonnage has been secured for the transhipment of the ore. Though Lincolnshire makers are not working at full pressure, there is a good demand for forge and foundry irons, and the figures paid are the maximum. Scrap is not so keenly inquired for, but the current prices are highly satisfactory to dealers, ranging from 5*l.* 5s. to 5*l.* 17s. 6d. for steel, and 6*l.* 10s. to 6*l.* 15s. for wrought iron. Manufacturers of high-speed steel still find the condition of the tungsten supply giving rise to much concern. The shipments of the wolfram ore from Australia and Burma are not developing on the extensive lines anticipated, but it is found that even in the distant orefields the labour problem has manifested itself. There is a shortage of manual assistance, and progress is also retarded by the lack of efficient transport facilities. British manufacturers, however, are much more favourably placed than their American trade rivals. Here high-speed steel is marked at 2s. 10d. for 14 per cent. tungsten to 3s. 10d. for 18 per cent. tungsten, whereas in the United States the figures are 12s. 6d. and 13s. 6d. respectively. Moreover, ferro-tungsten is 33s. in America as compared with 6s. 1d. here. American engineers are striving to get supplies of the tool steel from England, but Sheffield makers are experiencing such big demands for home and colonial business that the American customer is "crushed out." One of the most gratifying announcements concerns the export trade. Inquiries at the Cutlers' Company reveal, in the statistical return of the number of export certificates granted to manufacturers, that this branch of trade is being maintained at a very high level. The reports of various works extensions chiefly relate to firms on direct Government work, who are working under abnormal pressure. Steel works are still producing their full capacity for Government purposes. War Office contracts have been placed for clasp-knives, machetes, razors, tools, brushes, boot grindery, grindstones, railway plants, tablespoons and teaspoons, steels, and an electric secondary station. The foreign and colonial orders include tools, sickles, springs, saws, wire ropes, machine parts, knives, files, steel and cutlery.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Output of Pig-Iron.—The great and growing scarcity of pig-iron is causing anxiety, and hope is expressed that arrangements will be made so as to increase the production. Pig-iron manufacturers would be glad to re-light idle furnaces if labour and raw material were available for that purpose, and there are persistent rumours that men may be released from the army for the furnaces and mines and for other necessary work in connection with the production of pig-iron. It is stated that an additional furnace on hematite and another on basic iron will be put into operation at an early date. The number of furnaces in blast in this district at present is 69. The opinion is expressed in some quarters that if absolute embargo on shipments to neutral countries is maintained it will be possible, even with the present output, to meet the requirements of home consumers and the Allies. Home trade is quite of a hand-to-mouth kind, and owing to the shortage of iron some of the deliveries due on contracts to our allies are of necessity held up.

The Cleveland Iron Trade.—There is not much new to report concerning the Cleveland pig-iron trade. After having been stationary in price for some little time, warrants have shown an upward movement, and this has infused a little life into the market; but business is still on only a very limited scale. Buyers are keen, but iron is not to be had. An advance of half a crown by buyers of Middlesbrough warrants, bringing their offer up to 92s. 6d. cash, has altogether failed to bring sellers into the market. There has been no declared sellers' quotation for warrants since towards the end of March last. No. 3 Cleveland pig is quoted 95s. and upward for export, but in the continued absence of transactions the figures named are quite normal. For home consumption No. 3 and the lower qualities all remain at 82s. 6d.

Hematite Iron.—East coast hematite iron is even more scarce than Cleveland pig. Deliveries against contracts are kept up as well as possible, but they fall a good deal short of fully satisfying customers, and new export business is quite impossible, licences for shipment abroad being unobtainable even if the iron could be purchased. So short is the supply that permits for delivery to our allies under running contracts are only sparingly issued. Home buyers are eager to place orders, but they experience much difficulty in doing so. Makers have no iron to spare, are wel sold ahead, and are not at all disposed to entertain forward business. For home consumption Nos. 1, 2 and 3 still stand at 122s. 6d., and for export 140s. and upward is quoted.

Stocks and Shipments of Pig-Iron.—The stock of Cleveland pig-iron in the public warrant stores here, practically the only stock in existence, now stands at 33,626 tons, composed of 32,089 tons of No. 3, and 1537 tons of other qualities of iron, deliverable as standard. Since the beginning of the month the stock has been reduced by 5856 tons of No. 3, and 923 tons of standard iron, a total of 6779 tons. Under the conditions prevailing, shipments of pig-iron from the Tees must be regarded as on a satisfactory scale. So far this month they average 2047 tons per working day, the total despatches reaching 42,991 tons. To the same date last month the total loadings amounted to 36,411 tons, or a daily average of 1734 tons, and for the corresponding part of May last year the clearances were officially returned at only 6823 tons, or an average of 325 tons per working day.

Coke.—Demand for all kinds of coke is heavy, and supply is none too plentiful. Local requirements are large, and promise to increase. Average blast furnace sorts are very strong at 28s. at the ovens, and for qualities low in phosphorus up to the fixed maximum of 30s. 6d. at the ovens continues to be asked. Good foundry coke runs from 45s. to 47s. 6d., and gashouse coke is quoted 27s. and upward.

Foreign Ore.—There is not a great deal of new business passing in foreign ore, but excellent supplies are coming to hand on running contracts. The action of the Government in controlling chartering of steamers from Bilbao has brought the freight down, and boats have come to hand better, but the pressure for delivery is such that the available tonnage is still insufficient. Mine owners in Spain are taking a very firm stand, and the f.o.b. price of rubio of 50 per cent. quality at port of despatch is fully 18s. Controlled consumers are privileged through the Government to fix steamers Bilbao - Middlesbrough, at 17s. so that to them the ex-ship Tees price of best rubio is 35s.; but in the ordinary way in the open market the Bilbao freight is 18s. 6d., making the ex-ship Tees price 36s. 6d. Imports of foreign ore are to the port of Middlesbrough, so far this month, 153,276 tons.

Manufactured Iron and Steel.—Manufacturers of finished iron and steel are kept fully occupied on Government work, and there is much pressure for delivery of war material, both for home purposes and the Allies. Under the circumstances, the numerous ordinary commercial enquiries in the market attract little or no attention. Common iron bars are 13*l.* 15s.; best bars, 14*l.* 2s. 6d.; best best bars, 14*l.* 10s.; packing iron (parallel), 10*l.*; packing iron (tapered), 11*l.* 15s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 15s.; iron ship-rivets (¾ diameter), 16*l.* 10s.; iron ship-rivets (⅞ diameter), 17*l.* 10s.; steel bars (no test), 14*l.* 10s.; steel ship-plates, 11*l.* 10s.; steel ship-angles, 11*l.* 2s. 6d.; steel ship-rivets (¾ diameter), 17*l.* 10s.; steel ship-rivets (⅞ diameter), 18*l.* 10s.; steel sheets (singles), 18*l.* 10s.; steel sheets (doubles), 18*l.* 15s.; steel joists, 11*l.* 2s. 6d.; and heavy steel rails, 10*l.* 17s. 6d.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Business in the steam coal trade has been affected to some extent by current circumstances and difficulties. Tonnage has arrived, to a fair extent; but the loading pressure has been as great as ever, some vessels having been waiting for supplies for some weeks. For June and later deliveries it has been practically impossible to enter into new transactions in consequence of the uncertainties attending a proposed limitation of prices to France. The best Admiralty large steam coal has been, to some extent, nominal; secondary descriptions have made 54s. to 55s.; Monmouthshire Black Veins 54s. 6d. to 55s.; ordinary Western Valleys, 54s. to 54s. 6d.; Eastern Valleys, 50s. to 52s. 6d.; best bunker smalls, 32s. to 33s.; and cargo smalls, 25s. to 28s. per ton. In bituminous coal, best households have made 23s. to 24s. at the pits; No. 3 Rhondda large, 57s. 6d. to 60s.; smalls, 35s. to 37s. 6d.; No. 2 Rhondda large, 47s. to 49s.; and No. 2 smalls, 26s. to 28s. per ton. The latest quotation for patent fuel has been 50s. to 55s. per ton. Special foundry for export has been quoted at 52s. 6d. to 65s.; good foundry coke at 60s. to 62s. 6d.; and furnace coke at 50s. to 55s. per ton.

The Welsh Coal Trade.—Some important conferences have taken place between the President of the Board of Trade, representatives of the shipping interest and the coal export trade, with reference to the action of the Department in fixing the maximum freights for conveyance of coal to allied countries. A scheme for France having been finally approved, the Board of Trade now proposes to take similar steps with regard to Italy. The new agreement provides for the inclusion of steamers already chartered.—A meeting of colliery representatives and other coal exporters has been held at Cardiff to consider joint action over proposals submitted by Mr. Runciman to colliery owners for a limitation of the price of coal for shipment to France after June 1. It is understood that in the course of the discussion many objections were urged to an artificial limitation of prices. It was considered, in fact, that the scheme would be perfectly unworkable as no one who was not obliged to do so would send coal to France at a limited price if higher prices could be obtained elsewhere. It was further pointed out that it would be obviously unfair for any section of colliery owners or exporters to be compelled to sell coal at limited prices if other persons were permitted to secure a market at higher prices in other directions. In some quarters there was a disposition to regard the action of the Government as the first step towards taking over the entire control of the export of coal, and there was particularly strong objection to a proposal that French buyers should handle the business exclusively. Another objection raised was that while the fixed freights proposed to be brought into operation from June would give shipowners about seven times the rates of normal times, the proposed prices of coal would be less than 50 per cent. in excess of the levels at which quotations stood before the war, and thus this would not be sufficient to give colliery owners a profit after meeting greatly increased working expenses.

THE ELECTRIFICATION OF THE SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

MESSRS. MERZ AND McLELLAN, MM. INST. C.E., LONDON, ENGINEERS.

(*For Description, see Page 496.*)

Fig. 27.

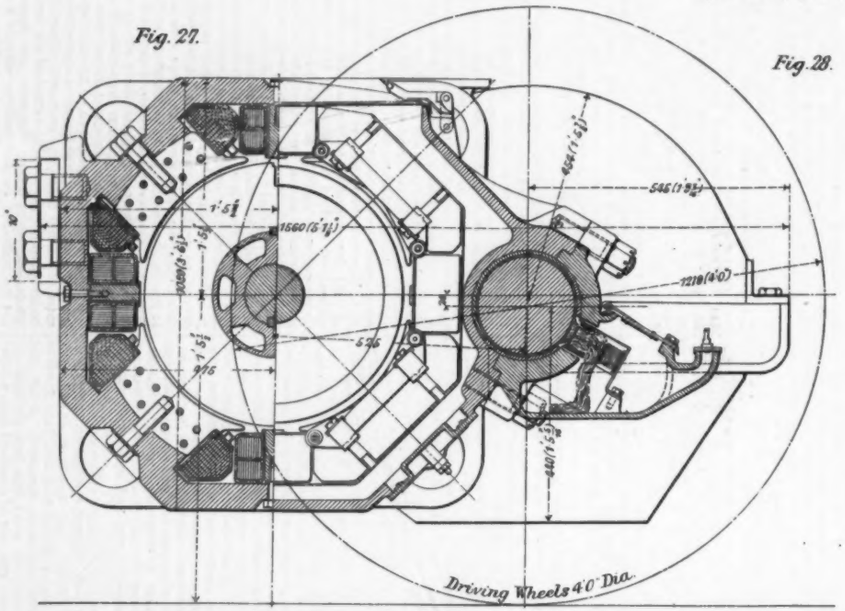


Fig. 28.

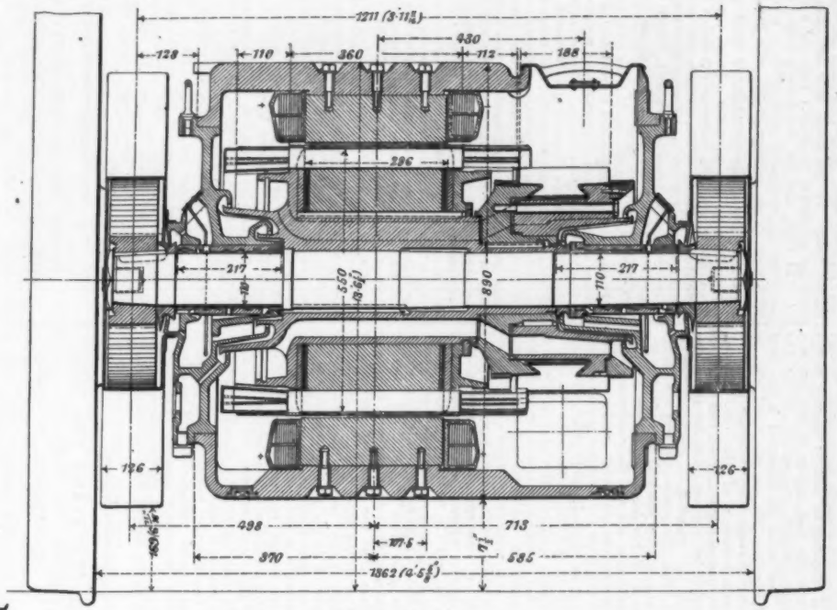


Fig. 29

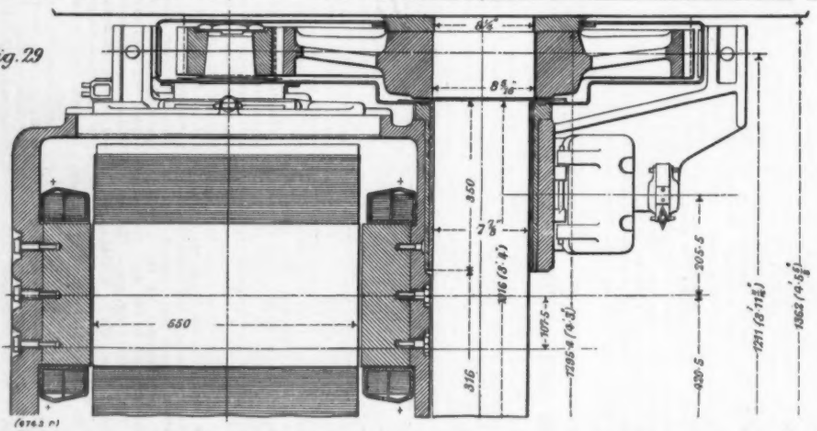


Fig. 30.

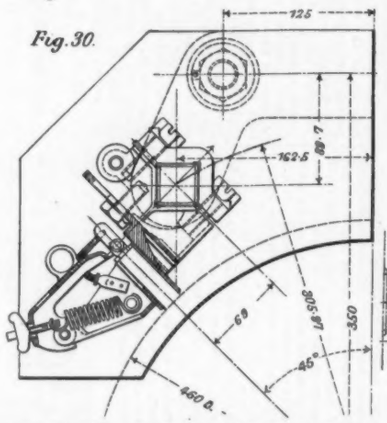
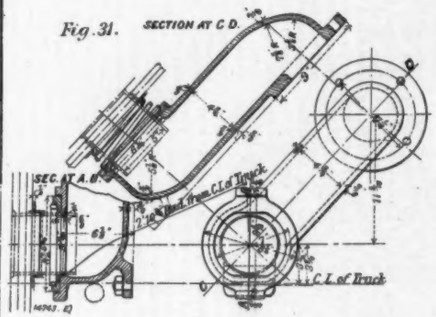


Fig. 31. SECTION AT C D.



THE ROYAL SANITARY INSTITUTE.—The subject given in 1915 for the Essay in the competition for the Henry Saxon Snell Prize was "Suggestions for Improvements in the Sanitary Arrangements and Appliances Suitable on Board Ship for (*a*) Passengers and Crew; (*b*) Cattle and other Live Stock." Seven essays were sent in, and they have been brought under the consideration of the Council. The adjudicators for the competition were W. Collingridge M.A. M.D., LL.B., A. Wellesley Harris, M.R.C.S., the late Herbert Williams, M.D., and Professor J. J. Welch, M.Sc., M. Inst. C.E., M.I.N.A. Acting upon the advice of the adjudicators, the Council have awarded the Prize offered of Fifty Guineas and the Silver Medal of the Institute to Wm. Hanna, M.A., M.D., Assistant Port Medical Officer, Liverpool.

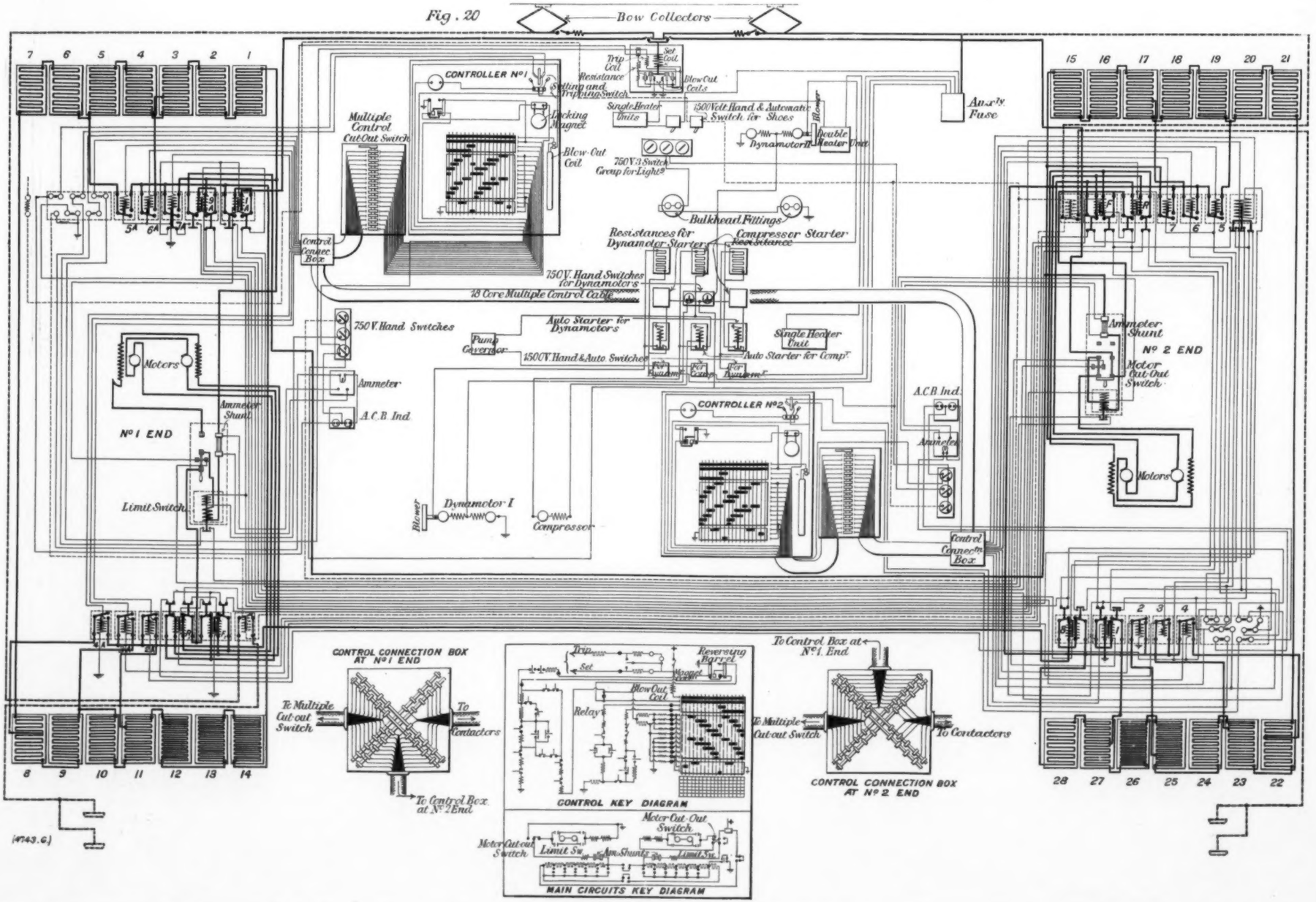
NIAGARA FALLS. — The Carborundum Company, Niagara Falls, has organised the Canadian Aloxite Company, Limited, as its Canadian branch, with a capital of 700,000 dols., to manufacture in Canada aloxite and other abrasives, and electric furnace products. A site of 8 acres has been obtained from the Canadian Niagara Falls Power Company at Stamford, near Niagara Falls, and power will be taken from that concern. The plant will have a capacity of 7000 horse-power, and will be brought into operation during the summer. The Canadian General Electric Company is supplying the electrical equipment. The Carborundum Company has recently purchased the plant of the Composite Board Company, which has been idle for four years. This comprises about 32,000 sq. ft. of floor space, and will be converted into a machine shop and general repair shop. The plant of the Ozone Vanillim Company, which is adjacent to plant No. 1 of the Carborundum Company, was also recently acquired, and has been converted into a grading plant.

THE ELECTRIFICATION OF THE SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

MESSRS. MERZ AND McLELLAN, MM. INST. C.E., LONDON, ENGINEERS.

(For Description, see Page 496.)

Fig. 20



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THE ELECTRIFICATION OF THE SHILDON-NEWPORT BRANCH NOR

CONSTRUCTED AT THE LOCOMOTIVE WORKS OF THE NORTH-EASTERN RAILWAY, DARLI[illegible], FRO

(For Descrip[illegible] Page 49

Fig. 21.

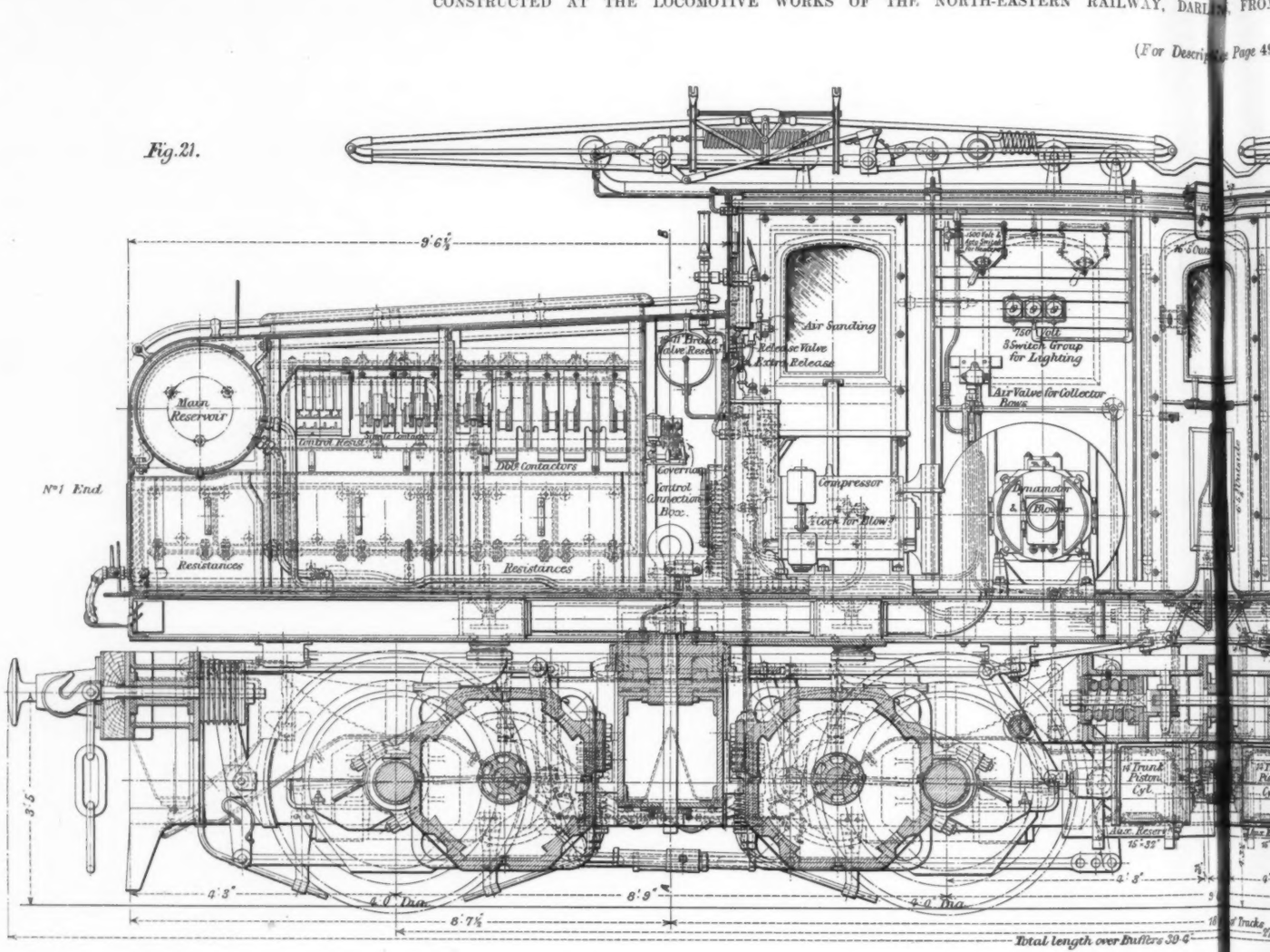
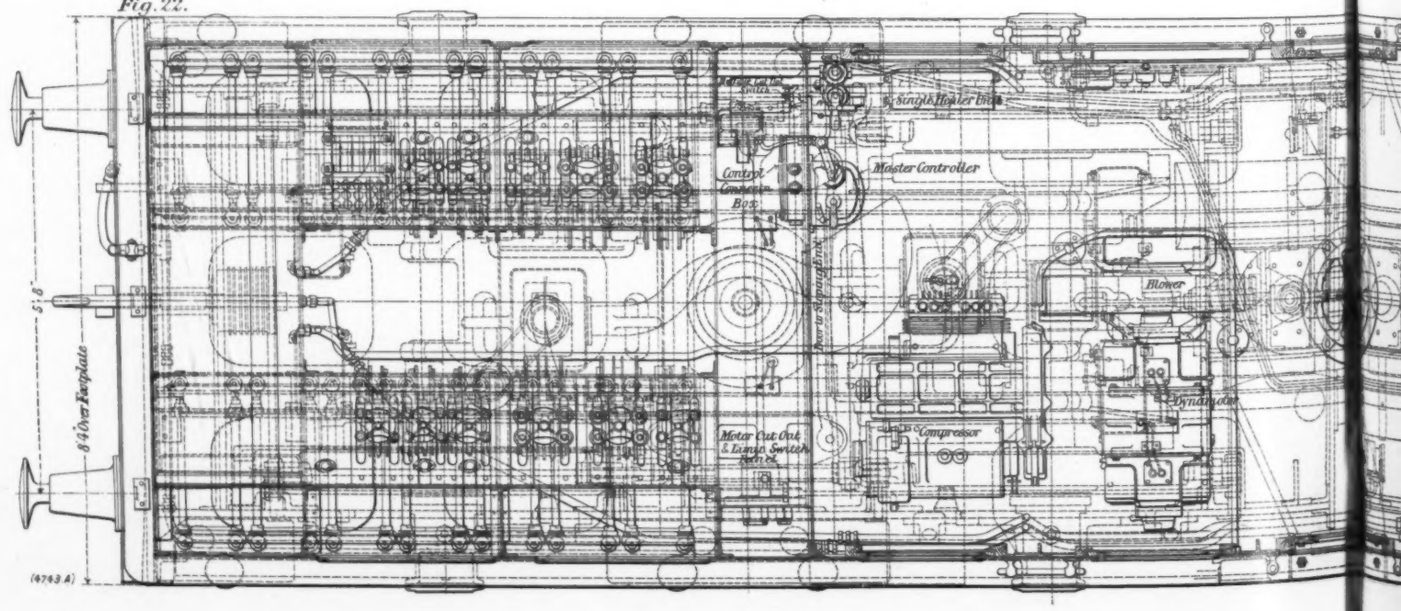


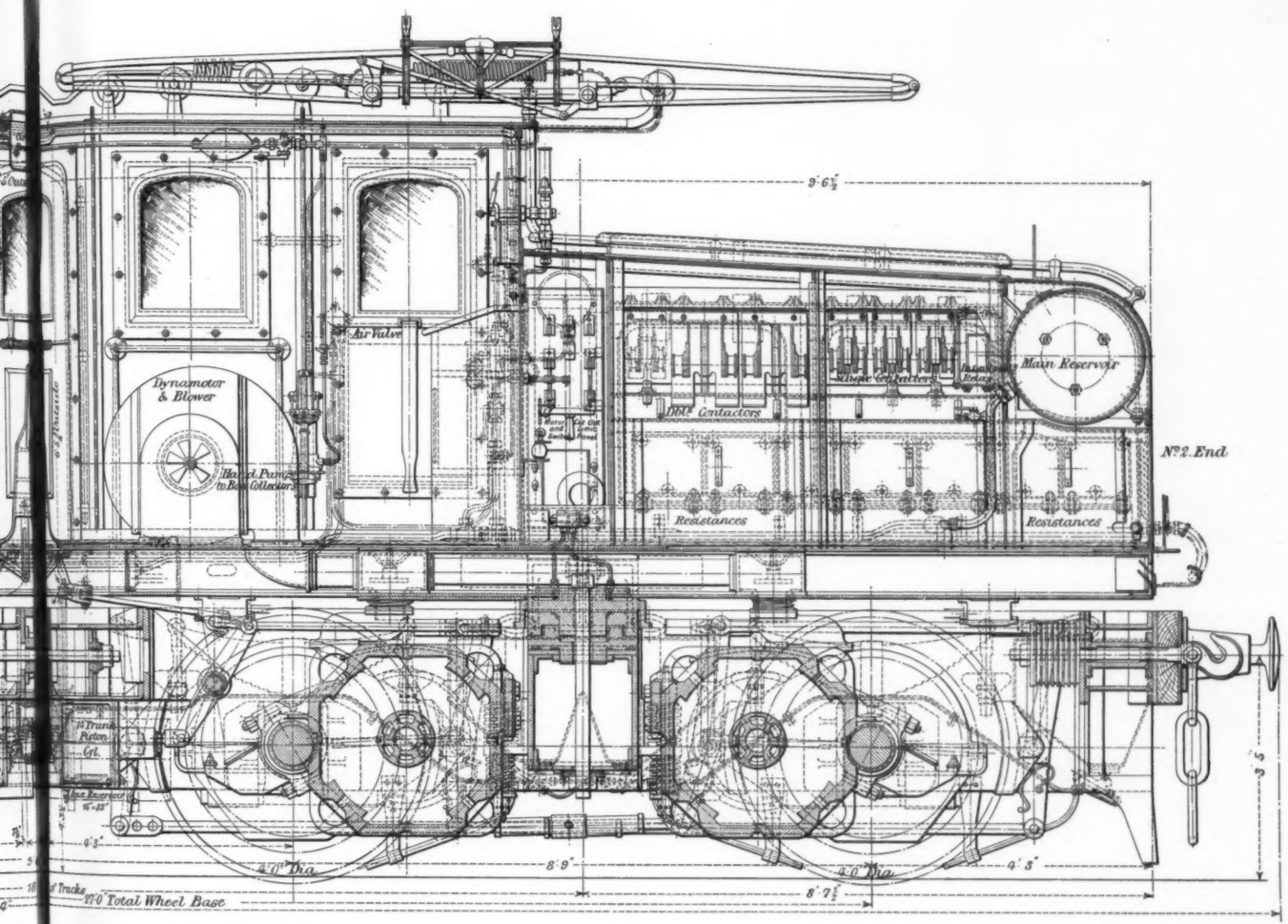
Fig. 22.

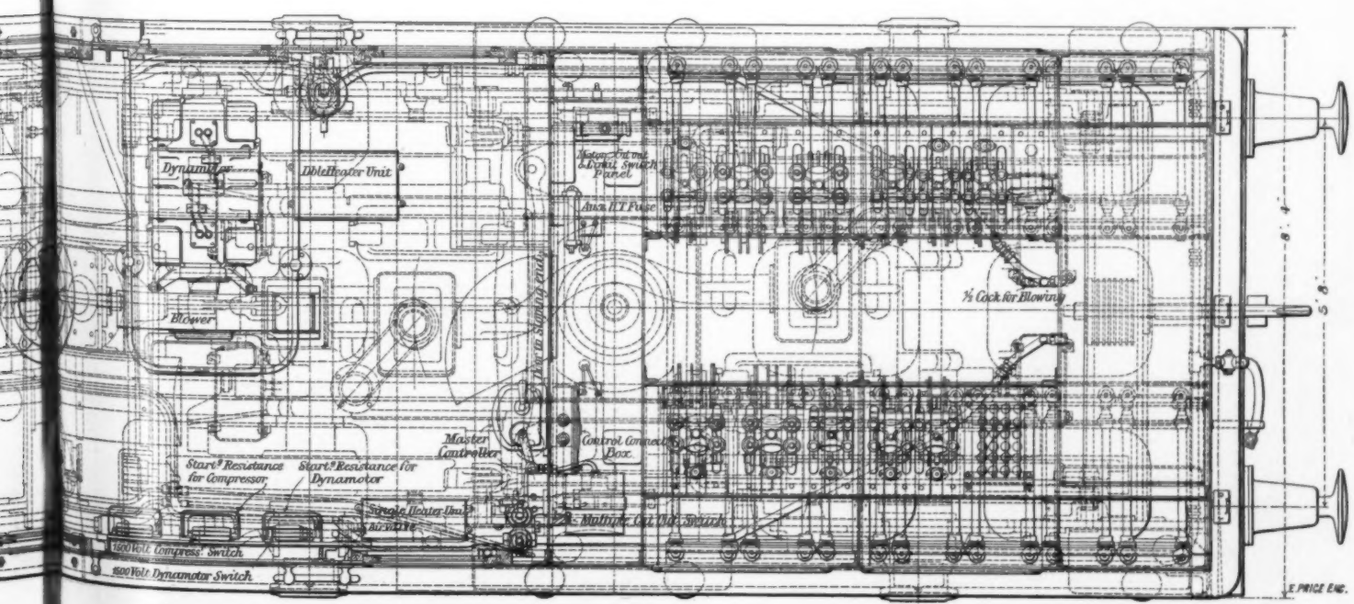


NORTH-EASTERN RAILWAY; HEAVY FREIGHT LOCOMOTIVE.

FROM THE DESIGNS OF MR. VINCENT L. RAVEN, CHIEF MECHANICAL ENGINEER.

(Page 496.)





ELECTRIFICATION OF THE N.E.R; HEAVY FREIGHT LOCOMOTIVE.

CONSTRUCTED AT THE LOCOMOTIVE WORKS OF THE NORTH-EASTERN RAILWAY, DARLINGTON, FROM THE DESIGNS OF MR. VINCENT L. RAVEN, CHIEF MECHANICAL ENGINEER.

(*For Description, see Page* 496.)

Fig. 23.

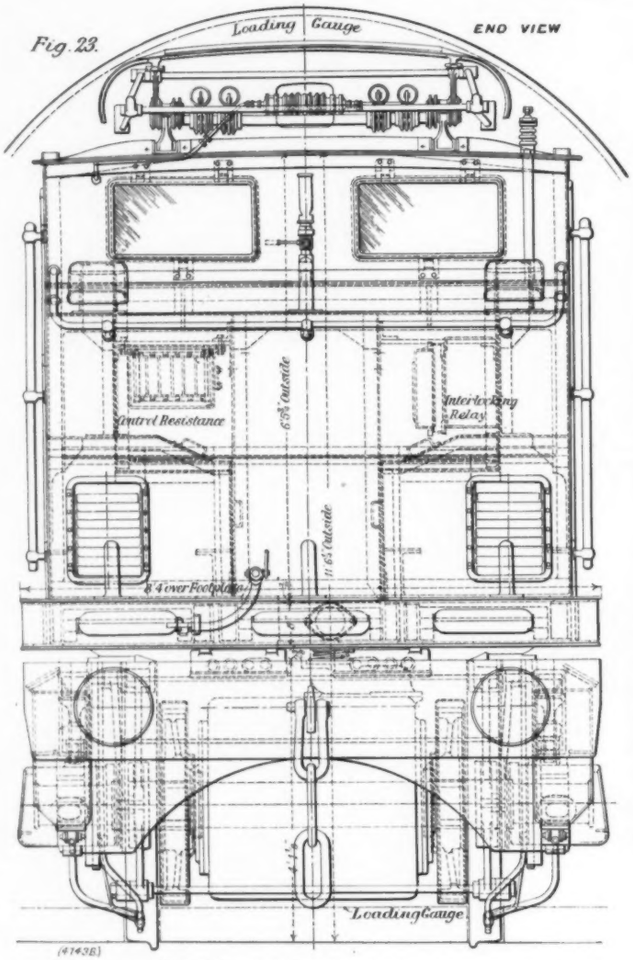


Fig. 24.

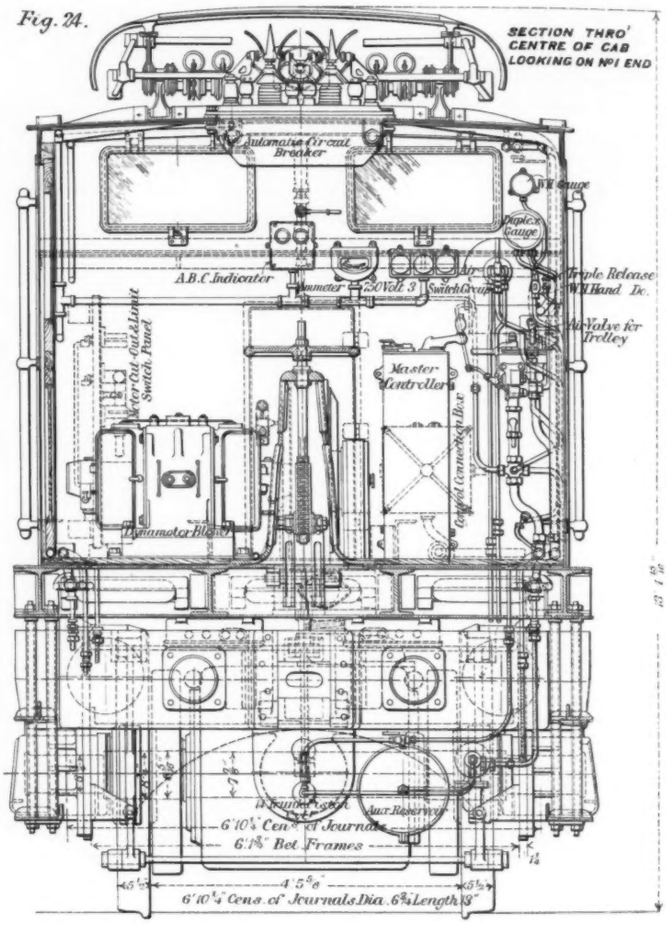
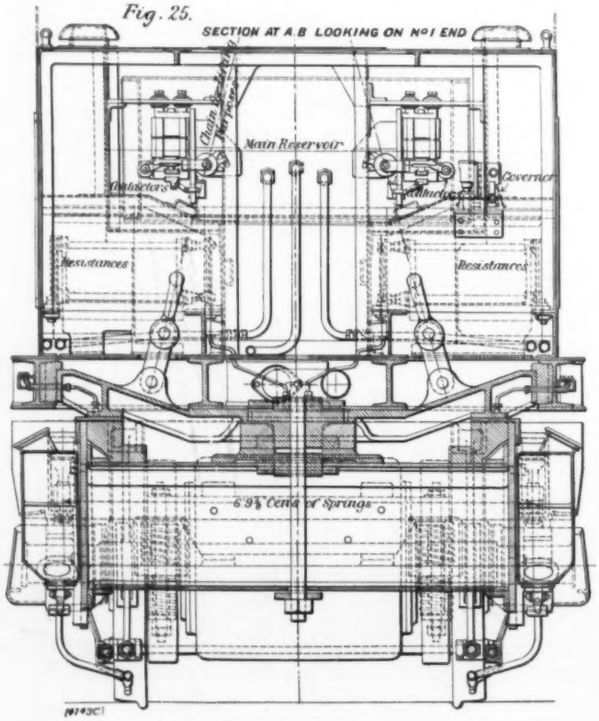


Fig. 25.



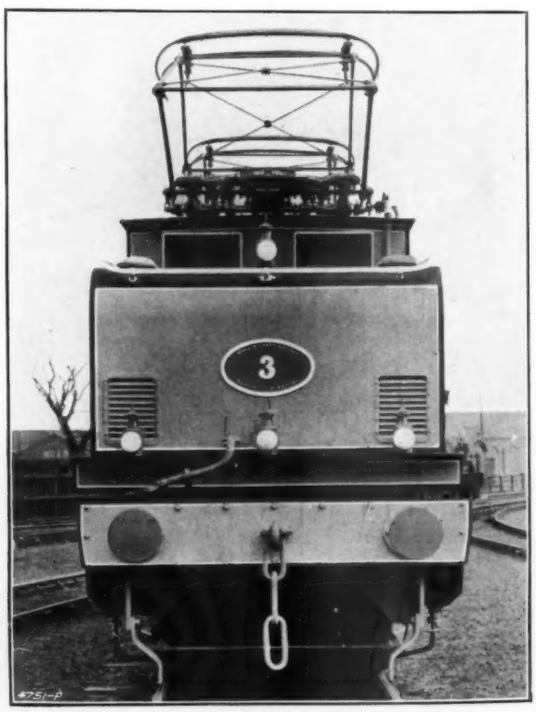


FIG. 26.

(*To face page* 591.)

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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"ENGINEERING" may be ordered from any Newsagent in town or country and at railway book-stalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance :—

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Thin paper copies	£1	11	6 ($7.65)
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All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C.

Offices for Publication and Advertisements, 35 and 36, Bedford-street, Strand, London, W.C.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8596 GERRARD.

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With One Two-Page Plate and Two One-Page Plates of the ELECTRIFICATION OF SHILDON-NEWPORT BRANCH, NORTH-EASTERN RAILWAY.

NOTICES OF MEETINGS.

THE PHYSICAL SOCIETY OF LONDON.—Friday, May 26, at 5 p.m., at the Imperial College of Science, Imperial Institute Road, South Kensington, S.W. 1. "The Correction of Chromatic Aberrations when the External Media are Dispersive," by Mr. T. Smith, B.A. 2. "Note on the Use of the Auto-Collimating Telescope in the Measurement of Angles," by Mr. J. Guild, A.R.C.Sc., D.I.C., F.R.A.S. 3. "The Viscosity of Colloidal Solutions," by Mr. Emil Hatschek.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—Saturday, May 27, at 3.30 p.m., at the Danum Hotel, Doncaster. A paper on "Earth Movements in the South Yorkshire Coalfield" (Part II.) will be read by Professor W. G. Fearnsides, M.A., F.G.S., Sorby Professor of Geology in the University of Sheffield.

THE SURVEYORS' INSTITUTION.—Monday, May 29, at 5 p.m. The annual general meeting of the Institution, to receive the Report of the Council and the announcement of the result of the Election of Officers for the ensuing year. The prizes awarded to successful candidates in connection with the recent preliminary and professional examinations will be presented by the President at the annual general meeting.

THE ROYAL SOCIETY OF ARTS.—Thursday, June 1, at at 4.30 p.m. A paper on "The Work of the Imperial Institute for India" will be read by Professor Wyndham R. Dunstan, C.M.G., M.A., LL.D., F.R.S., Director of the Imperial Institute. The Right Hon. Lord Islington, P.C., G.C.M.G., D.S.O., Under-Secretary of State for India, will preside.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, June 2, at 5.30 p.m. A discourse will be delivered by Lieutenant Paul Hyacinthe Loyson. The subject is "La France dans l'Histoire comme Champion du Droit." Afternoon lectures next week at 3 o'clock. Tuesday, May 30. Mr. Thomas Martin Lowry, D.Sc., F.R.S., Lecturer on Chemistry, Guy's Hospital Medical School, on "Optical Research and Chemical Progress" (Lecture I.). Thursday, June 1. Sir Alexander Mackenzie, Mus. Doc., D.C.L., LL.D., Principal of the Royal Academy of Music, on "Chamber Music and its Revival in England" (Musical Illustrations) (Lecture II.). Saturday, June 3. Professor Sir James G. Frazer, D.C.L., LL.D., D.Litt., Professor of Social Anthropology, Liverpool, on "Folklore in the Old Testament" (Lecture I.).

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, MAY 26, 1916.

THE WAR AND FRENCH INDUSTRIAL ACTIVITY.

WE know what a considerable influence the present war is having upon our own commercial and industrial activity. The effect of the war in countries like France, for example, where compulsory military service is the natural order of the day, and where conscription calls to the Colours all the manhood of the nation from twenty to forty-eight years of age, is more considerable still. It is true that in France there are certain rules and regulations which attenuate in a measure the depletion of the industrial classes, by acting for maintenance in the factories or for sending back to them from actual military duties a number of special craftsmen to work on the various munition supplies. On the other hand, youths of nineteen years of age (those of the 1916 class) have been called to the Colours before their time, and those of the 1917 class are now being called up for preparatory military drill. It is true, further, that very many of the older groups of men have not so far been called up for active military duties. Nevertheless, conscription, from the very first days of mobilisation is: the first week of August, 1914, has had a considerable effect upon French industrial life. In the space of a few hours the works, transport companies, and commercial establishments were all compelled to allow their staffs to leave, the younger members having to report at headquarters within twenty-four or forty-eight hours.

Mobilisation on the extensive scale which obtains in France was bound greatly to slacken the activity of a great many establishments, and to cause others to come to a complete standstill, even in cases where male labour played only a secondary part, and could on an emergency be replaced by female or child labour. In many instances it was only sufficient for the chief of an establishment or for a few specialists to be called away when manufacture or trade was completely arrested until a substitute was found or new specialists trained. The fact should not be lost sight of that mobilisation also upsets all commercial intercourse; most of the railway lines momentarily ceased all commercial traffic; further, that all private means of transport, horses, cars, omnibuses, lorries, &c., were commandeered immediately hostilities broke out. The commandeering of ships took place at the same time. Postal and telegraphic communications suffered very great delays, and the use of the public telephone was suspended entirely. Payments were required almost exclusively in net cash, whilst coin and bullion disappeared almost entirely from circulation. Fuel became scarce and increased largely in price.

Records which were drawn up in October, 1914, by the Labour Inspectors showed that on an average about 44 per cent. only of the operatives normally at work were employed on that date. The percentage varied greatly with the trades. For example, the difference between the normal staff and the staff employed on January 1, 1915, was only 29 per cent. in the food trades, but it reached 41 per cent. in the chemical industries, 50 per cent. in the rubber, paper and cardboard trades, 62 per cent. in the book and publishing trade, 69 per cent. in the wood-working trade, 78 per cent. in the building trade, and 88 per cent. in the precious stone and jewellery trade. In this latter, as in several other luxury trades, other causes, natural in the circumstance, intervened, for the number of mobilised men in the precious stone and jewellery trade did not exceed 23 per cent., whilst the percentage was 32 in the cartage and transport, 33 in the building, and 26 in the food trades. The proportion was 15 per cent. in the textile trade, in which women and children are occupied in large numbers in normal times, and 6 per cent. in the clothing and allied trades. As a matter of fact, the average proportion of 44 per cent. above referred to corresponded with a mobilisation for military duties of about one-third the normal number of male workers; the proportion of unemployed was about 20 per cent.

The great disorganisation of trades throughout France caused by national service only lasted a comparatively short time, for means were gradually taken to replace the absent men by female labour, and, as far as was practicable, by refugee labour from Belgium and from the districts momentarily occupied by the enemy. As a general rule, the employers who, after matters had settled down somewhat, found themselves in a position to employ their staff, readily gave them work, with a view to enable them to earn a living. The victory of the Marne, in September, 1914, had a favourable influence upon trade conditions generally, and as early as the following month of October matters commenced to wear an improved aspect, the more so as the conditions of the moratorium were at the same time rendered less stringent. Added to this, railway traffic was improving; the military authorities were ordering largely from the textile, hosiery, boot and shoe trades; also from the steel-makers, and from engineering and other works. Close upon the end of 1914, a very marked improvement could be noticed in commercial railway traffic conditions and in the postal service.

As the needs of the civil population in regard to food and clothing had to be met, it was found that a large proportion of the establishments which had closed in August, 1914, were open and trading in January, 1915. Taken as a whole, the proportion of establishments open and at work in January, 1915, was 71 per cent. of the total number included in the inquiry made by the Labour Inspectors, a figure which pointed to a marked improvement. Taken as a whole also, the number of men at work in January, 1915, was an average of about 59 per cent. of the total number at work in normal times in the establishments considered, whilst at the outbreak of hostilities the proportion was only 34 per cent. In individual trades the proportion varied with the trade and with the distance from the war zone.

As a matter of course, the meeting of the needs of the armies has played an important part in fostering the industrial and commercial activity of the nation. For many months past, the flour mills, bakeries, and meat-packing firms have been in full activity, and have been compelled greatly to increase their staffs. The biscuit manufacturers have organised their plant for making bread, and have also greatly increased the number of their operatives. The textile works have been fully employed in the making of flannel for the troops;

silk tissues for powder-bags; jute fabrics for articles of equipment; heavy canvas for tents, kit-bags, &c. The leather trade has had to cope with the military requirements in regard to boots, gaiters, cartridge-belts, and so forth; the wood-working trades have had to build barracks and their fittings, to build and repair army wagons, and to manufacture packing-cases for supplies, the carriage of shells, &c. Metallurgical and engineering works have long since specialised in the production of war material of all classes.

Unfortunately, the removal for the time being of a number of specialists from their avocations, and the congregation of all available labour into the establishments engaged on war work of one kind or another, have greatly impeded all other industrial pursuits, and have been conducive to a great decrease in the French commercial exports. Scarcity of hands has been heavily felt in coal-mining, in which female and child labour is practically non-existent. In August, 1914, the Comité Central des Houillères de France found only 31,000 operatives at work in the French coal-mines, a figure which fell to 30,000 in September, and rose to 40,000 in October, and to a slightly higher total still in the month of November following. In normal times the French coal-mines occupy about 240,000 operatives, all told, and embracing also the territories which are temporarily invaded by the enemy. From the commencement the miners available did not hesitate to increase their efforts to meet the country's need, and they work 6 to 6½ days per week, and 11 to 12 hours per day. Their number at the present time is about 44,000.

Inquiries, which have been repeatedly held by labour inspectors in regard to the activity of industrial and commercial establishments throughout France, point to a gradual improvement, notwithstanding the maintenance with the Colours of practically the totality of the men mobilised for active military duties. An inquiry held in April, 1915, covered slightly over 27,000 establishments, occupying in normal times 1,098,000 operatives; it was ascertained that the operatives at work at that date showed an average of 65 per cent. of the normal, as compared with 34 per cent. in August, 1914, 44 per cent. in October, 1914, and 59 per cent. in January, 1915. These figures are average total proportions. The difference between the 65 per cent., the proportion of operatives at work in April, 1915, and 100 does not give the proportion of unemployed. The number of men mobilised with the Army has to be taken into account; it forms about 24 per cent. of the total *personnel* of both sexes and of all ages in all the establishments considered. Unemployment was specially marked in several trades, such as the printing and book trades, the precious stone and jewellery trade, the building trade, &c. On the other hand, in the food trades, in metallurgy, in transports, the lack of operatives caused by mobilisation was more than compensated for in a comparatively short time by the afflux of operatives who were strangers to these trades before the outbreak of hostilities. New staffs were formed, female labour being frequently resorted to for operating machine-tools, working reheating furnaces, and operating textile machinery. In the textile trades, eleven and twelve hours are being generally worked, the Labour Bureaux having sanctioned the measure, which the operatives, both male and female, have readily agreed to, owing to the exigencies of national defence. In the iron and steel trades the number of men has long been greater than in peace time, the hours are twelve per day, and the peace-time wages have only risen by 15 to 20 per cent. at the utmost.

In the collieries matters have not improved as much as would be desirable. In the second half of 1914 the output was only 9,348,000 tons, as against 20,439,000 tons for the first half-year. The total for 1914 was therefore 29,787,000 tons, as against 40,844,000 tons, which was the output for 1913. In this connection it should be remembered that a number of collieries in Northern France are in the invaded districts.

The figures we give above for April, 1915, were improved upon in the following July. The situation was further improved by the fact that over 30,000 women were working in private factories at the manufacture of shells, rifles, bombs, grenades, cartridges, fuses, aeroplanes, dirigibles, &c., whilst about half that number were being employed in the State factories and arsenals. Numerous others were being given employment in the various phases of biscuit manufacture; in the chemical, paper, printing, book, leather, boot, wood, and other trades; in foundries, in the making of cores; and in the making of autogenous welds.

Information gathered by the Labour Inspectors in October last bears on 44,000 establishments, occupying in normal times 1,542,000 operatives. In August, 1914, 48 per cent. only of these establishments were in work, a proportion which rose to 57 in October, 1914, to 65 in January, 1915, to 72 in April and to 77 in July, 1915. The percentage was 81 in October last. In that month the operatives in the 44,000 establishments in question numbered 1,139,000 of both sexes, or 74 per cent. of the total in normal times. The men mobilised numbering 24 per cent., there remained only 2 per cent. as the proportion of unemployed.

Many skilled men, specialists in their particular avocation, are still away from the factories; these men, being in the full vigour of their age, have been called for service with the Colours. The military authorities, however, have repeatedly sent back to the factories a number of these men when their special skill has been deemed indispensable for national defence; the authorities continue to follow the same course when circumstances demand it. Coal-miners have been among this class, and their return to the collieries has proved a great benefit to the community; the measure has enabled the collieries of the St. Etienne basin, in the centre of France, to yield about 85 per cent. of their normal output. The mining squads have been completed as far as was possible by miners from the invaded regions of France and Belgium. The refugees have not always readily taken to the work that was offered them; notwithstanding the openings available in all classes of trades, they preferred in a number of instances to remain content with the aid, meagre though it was, distributed to them. The various institutions, however, managed to place 4400 refugees in metallurgical works and 1200 miners in the collieries, from November, 1914, to January, 1915. An official bureau has also been formed to find hands for all agricultural pursuits.

As regards more particularly metallurgy and engineering, employers and men have vied with each other in their efforts to promote manufacture for national defence. As above stated, when the services of a man mobilised at the Front were found necessary in any establishment, the man has been called back to work at his calling. Men in other trades, being skilled workmen, were taken on in large numbers to work on munitions, this measure being, of course, facilitated by the use of modern machine-tools. On the other hand, the distribution of monetary help to unemployed and to the families of men who have been mobilised for military duties, has had an influence in restraining labour, an influence which is still being felt. It was, of course the duty of Government to aid the families whose breadwinner was called to the Colours; but when the first commotion was over, and when the intense requirements of the Army were ascertained, adequate means should have been taken to replace monetary aid by work distributed to the various members of a family. But matters in this respect also are improving day by day.

DRY-POWDER FIRE-EXTINGUISHERS.

THE menace of incendiary bombs, to which a large part of the eastern side of this country is continually subject, has caused the householder to consider seriously the question of extinguishing fires immediately they break out, and before they have time to obtain serious hold on his premises. To do this he must have appliances ready at hand, for it is clear that it is only during the first minutes, or rather seconds, that any domestic means will be of avail. A good many such appliances are advertised, and large numbers have been bought on the strength of the recommendation of their makers. Prominent among these are the so-called dry-powder fire-extinguishers, which offer the advantages of moderate outlay and small size. So far they are exceedingly attractive to the man who is seeking to protect himself easily and cheaply, and if they were really effective their cost would be money well spent. It betrays, however, a want of appreciation of the scientific capacity of the German mind to suppose that the army will equip their expensive Zeppelins with bombs of so small capacity that they can be extinguished by sprinkling them with a little powder. Our Fire Brigade officers formed a very decided opinion as to the merits of these appliances long ago, and the Metropolitan Police have issued several warnings against putting reliance in them. But still the sale goes on, and, therefore, to demonstrate the exact value of such appliances the Home Secretary appointed a committee of four members—Major A. McN. C. Cooper-Kay, C.B., Major T. H. Crozier, Dr. J. A. Harker (National Physical Laboratory), and Lieut.-Commander S. Sladen, R.N.—to conduct experiments to test the value of dry-powder fire extinguishers.

The committee were fortunate in securing a site comprising a number of condemned cottages, in which fires could be originated. These were close to the London Fire Brigade headquarters, so there was no danger of a fire attaining serious proportions if the appliances under test failed to arrest it. Ground-floor rooms were roughly filled with wooden furniture, 28 lb. of shavings, 28 lb. of firwood, ½ in. square by 18 in. long, and 1½ lb. of celluloid being laid in each room. Then an incendiary bomb was dropped through the first floor, and allowed to burn for a given period before the fires were attacked by the following appliances:—

Room A.—Dry-powder extinguishers, not exceeding six tubes.

Room B.—Water in buckets, not exceeding six buckets containing two gallons each.

Room C.—Liquid chemical extincteurs, not exceeding six extincteurs of two gallons capacity.

In all cases the application was made by an unskilled person, representing the average householder. Each bomb was allowed to burn 45 secs. before the fire was attacked, the powder in each case being "Kyl-Fyre." The intention of the committee had been to allow the fire to burn for three minutes, but it was found that the resulting fire was so fierce that the operator was unable to approach near enough to apply the powder extinguishers. This is a point of much importance, for it is seldom that the householder will be so self-possessed, after a bomb has fallen through his roof, as to get his extinguisher at work in 45 secs. Unless he has three or four in every room in the house, and is most prompt in bringing them into action, it is quite likely that the powder will never come into contact with the fire at all. There is, of course, no pressure behind it to project it, and in this respect it suffers in comparison with a water jet from a hose, which can be thrown from a distance. It was found by the committee that 18 gallons of water from a small hose extinguished a fire which had had several minutes' start, and which could not be approached for the application of powder.

In one test the bomb was well alight in 5 secs., and the contents of the room were burning fiercely in 40 secs. The first tube of powder was applied at 45 secs., and five additional tubes during 35 secs., the flames being reduced to about three-quarters of their original area at the end of this time (80 secs.). An interval of 40 secs. was allowed during which the fire was permitted to increase, reaching its original intensity at 2 minutes, after which it was extinguished by hose.

Another test was made out of doors. 21 lb. of firwood, cut to ½ in. square and 18 in. long, was laid on the ground in a circle about 4 ft. in diameter, and a bomb dropped in the centre. The first tube of powder was applied at 13 secs., the second at 17 secs., and the third at 24 secs. The three had a dulling effect only, the flames from the burning wood being temporarily checked. The wood was quickly re-ignited by the bomb, and at the end of 3 minutes was well alight and burning freely. It was then extinguished by a hose.

A third test was made with a wooden structure about 6 ft. square, with a wooden floor covered with 14 lb. of shavings and 14 lb. of wood, cut as above, sprinkled with half a gallon of paraffin. The

shavings were ignited by a fusee, and were well alight at 25 secs.; in 30 secs. the walls were alight, and in 45 secs. the floor alight all over. The flames rendered approach to within 15 to 30 ft. distinctly unpleasant. The first powder was applied at 2 minutes with temporary dulling effect; the second at 2 mins. 22 secs., with the same effect, while the third at 2 mins. 39 secs. partly subdued the fire, which, however, increased again in intensity, and after 5 minutes was extinguished by a water jet.

We have not space to detail the results of the tests with buckets of water and chemical extincteurs. They may be stated briefly, however. Three buckets of water or three extincteurs were quite sufficient, and sometimes more than sufficient, to extinguish the fires. Not only did they smother the flames, but they also cooled the burning material, so that it did not so readily relight when the smothering effect passed off. The action of the powder seems to depend upon cutting off the supply of oxygen, firstly mechanically, and secondly by the liberation of carbonic acid. Analysis of four different samples of dry powder from fire-extinguishers shows that it contains from 42 to 55 per cent. of sodium bicarbonate, and from 1 to 50 per cent. of calcium carbonate, the available percentage of carbon dioxide varying from 11 to 15 per cent. If the whole of this were given off suddenly, approximately 1 cub. ft. of gas would be formed from each pound of powder used—that is, 12 cub. ft. of three tubes of powder. It may be doubted whether this small quantity has any appreciable effect on the fire, and the probability is that the powder acts merely mechanically. However, it is only fair to state that the application of sand was (weight for weight) less effective than the dry powder. It is, naturally, enormously cheaper.

The series of experiments demonstrated again the fact, well known to all fire experts, that burning material must be cooled if it is not to burst again into flame as soon as the air gets access to it. Of course, if it can be buried under a deep layer of inert material, and left there for hours or days, the fire will gradually die out. But this result cannot be attained by tubes of powder weighing 4 or 5 lb. each. These are simply toys when employed against the fierce heat of incendiary bombs. Fortunately these do not burn long, but they attain an exceedingly high temperature, and ignite everything around them. It is absurd to try to bottle up this heat with a thin layer of powder. It must be carried quickly out of the building, and there is no agent for this purpose equal to water, with or without carbonic acid. Even water will not extinguish the bomb itself, unless applied in very great quantities.

The committee reported to the Home Office on April 27, and their report [Cd. 8250, Price 1d.] was presented to Parliament last Tuesday. Their opinion is summed up in the following words:—"The spread of the fire caused by the bomb was greatly limited, and in some cases totally prevented, by the application of water; whereas after the application of the dry powder the fire continued to burn, although at each application some temporary check to the fire was noted."

TRADING WITH THE ENEMY AND PATENTS.

THE Patents, Designs and Trade-Marks (Temporary Rules) Act, 1914, empowered the Board of Trade to make rules, and to do such things as they thought expedient for avoiding or suspending in whole or in part any patent granted to the subject of a state at war with His Majesty, and this Act further empowered the Board of Trade to grant licences to British subjects to make, use, exercise or vend patented inventions liable to avoidance or suspension. At the time this Act came into force we reviewed many of the decisions that were given on the advice of the Patent Court, which consisted of the Comptroller-General of Patents (Mr. Temple Franks) and the late Comptroller-General of Patents (Sir Cornelius Dalton). During the whole of the war the Patent Office has been receiving and dealing with applications for patents from alien enemies, and such applications have been allowed to proceed through all the stages as far as the acceptance and printing of the complete specification. At this point the procedure has been held up, and the sealing of the patents delayed until after the war. As a consequence there are in the Patent Office a number of what may be called "unsealed patents." Under the Patents (Temporary Rules) Act it was not possible to apply to the Board of Trade for a licence under these "unsealed" patents because, strictly speaking, they had not matured into patents. A position therefore arose that protected the inventions of alien enemies from attack under the Patents (Temporary Rules) Act. This position of affairs could not be allowed to remain, and as a consequence a section (No. 6) was inserted in the Trading with the Enemy Amendment Act, 1916, providing that if the benefit of an application made by or on behalf of or for the benefit of an enemy or enemy subject for any patent was, by an order under the Trading with the Enemy Amendment Act, 1914, or the 1916 Act, vested in the custodian (*i.e.*, Public Trustee), the patent might be granted to the custodian as patentee and might, notwithstanding anything in Section 12 of the Patents and Designs Act, 1907, be sealed accordingly by the Comptroller-General of Patents, and any patent so granted to the custodian should be deemed to be property vested in him by such order as aforesaid.

This new enactment throws what we have called "unsealed" patents open to applicants for licences. An application of considerable interest, the first under this new legislation, has been made to the Patent Court. The application was made on behalf of two Sheffield firms, and the invention, which was made by two German engineers, named Dinger and Timmer, of Solingen (the German Sheffield), related to machines for making blades. The two Sheffield firms were Messrs. Thomas Turner and Co. and Messrs. Needham, Veall and Tyzack, and they required to use this invention in order that they might fulfil a War Office contract of such an extensive nature that it could not ordinarily be complied with. The Comptroller-General intimated that the application would be granted, and in doing so he made clear the procedure that would be adopted in the future in this class of case. The Public Trustee will be made the custodian of all the "unsealed" patents, and while the licence has hitherto been issued by the Board of Trade, the licence on "unsealed" patents will be executed by the Public Trustee, and granted in his own name, though it will be prepared by the Solicitor of the Board of Trade. The Public Trustee will hold the royalties, but somebody will have to pay the sealing fee, for an "unsealed" patent must be sealed to someone before a licence can be granted. We believe there are upwards of two thousand of these "unsealed" patents, and of these a large number of inventions will be doubtless of interest to British manufacturers, who will no doubt take full advantage of the new range of inventions now thrown open to exploitation.

THE LATE SIR CORBET WOODALL.

THE news of the death of Sir Corbet Woodall, which took place at Torquay on the 17th inst., will be received with general regret, the deceased gentleman's unfailing courtesy and great accessibility having contributed largely to the unique position which he occupied in connection with the gas industry. Indeed, it is difficult to see how, under the changed conditions of to-day, a similar pre-eminence could be attained by his successors.

Sir Corbet Woodall was 75 years of age at the time of his death, having been born at Liverpool in 1841. He had an hereditary connection with gas undertakings, his father having been manager of the Wolverhampton works. His own professional career commenced at the Burslem Gas Works, of which his elder brother was then manager; but his stay here was short, as in 1859 he was apprenticed to the late Mr. Henry Morton, then engineering manager to the Woolwich Equitable Gas Company.

In 1865, when but 24 years old, he was entrusted by the Stockton Corporation with the reconstruction of their gas works, and they were so satisfied with his services that by a special resolution of the council he was awarded an additional gratuity of 100 guineas. During this period he also acted as consulting engineer to a number of gas works in the neighbourhood, and in this capacity was responsible for the works of the North Ormesby Gas Company. In 1869 he returned to London, taking service with the Phœnix Gas Company at the Vauxhall Works, under his old chief, Mr. Morton, whom he ultimately succeeded as engineer to the company. In this capacity he constructed in 1878 a gasholder at Kennington Lane. This was the largest built up to that date. The tank measured 218 ft. in diameter, and the designed capacity was 3,100,000 cub. ft. At about this date the advent of commercially practicable systems of electric lighting seriously perturbed the holders of gas shares. The embankment had been lighted electrically in 1878–79. In conjunction with Mr. Wm. Sugg, Sir Corbet did much to re-establish confidence by his demonstrations that high-power gas lighting was practicable if the public were prepared to pay the price. Of course, the gas mantle had not then been invented, but the electric lamp of that date was also far from efficient, so the contest was by no means an unequal one. Sir Corbet recognised, nevertheless, that the new illuminant was to be seriously reckoned with, and he became a strong advocate of the policy of combining gas and electric undertakings in the same hands. This policy he was later on able to give effect to in the case of the Tottenham District Gas Light and Power Company.

On the amalgamation of the Phœnix Gas Company with the South Metropolitan undertaking, Sir Corbet received a retiring allowance, and commenced practice as a consulting engineer at Westminster. His success in this capacity has been remarkable. He became a leading expert witness at parliamentary inquiries, and his services as arbitrator were in very great request.

He was consulting and inspecting engineer to the Imperial Continental Gas Association and to the Australian Gas Light Companies, as well as to many similar undertakings in this country. He did much to introduce here the use of carburetted water-gas.

He joined the Institution of Civil Engineers in 1872, becoming full member in 1877. In 1882 he was elected a member of the Institution of Mechanical Engineers. He was president of the British Gas Association in 1878, of the old Institution of Gas Engineers in 1897, and of the present Institution in 1913. In this latter year he was also president of the British Commercial Gas Association, and of the Society of British Gas Industries. In 1912 Leeds University conferred on him the honorary degree of D.Sc. He was knighted in 1913.

In addition to Sir Corbet's engineering work, he exercised administrative functions on a very large scale. He became a director of the Imperial Continental Gas Company in 1902, and at a still earlier date was appointed to the Board of the Gas Light and Coke Company, of which he became Governor in 1906. He was also connected as director with many other gas undertakings. He was a warm advocate of the policy of co-partnership, and was responsible for the introduction of the system into most of the gas undertakings with which he was connected. In the case of the Gas Light and Coke Company the plan was inaugurated in 1907.

Sir Corbet was a strong supporter of the Territorial Force, and as far back as 1908 stated publicly that if the force were not made a success compulsory service would be necessary, and "the sooner the better." The difficulties which employers put in the way of men joining this force were strongly condemned in his presidential address to the Society of British Gas Industries in 1913.

Sir Corbet was also largely responsible for the scheme adopted by the London County Council for the training of lads as gasfitters.

His son, Mr. Henry Woodall, has for many years been associated with his father in his practice as consulting engineer at Palace Chambers, Westminster. Of his other sons, two are now engaged on active service, whilst a fourth is the general manager of the Brooklyn Borough Gas Company, Coney Island.

AMERICAN BILLETS.—The imports of American billets, blooms, and slabs into Great Britain between August and December, 1914, amounted to 9342 tons; in 1915 they were 349,046 tons; and in January and February this year 21,330 tons, making an aggregate of 379,718 tons. Since the war started the United States have furnished nearly 89 per cent. of the imports of semi-finished steel into Great Britain.

NOTES.

LOW EXPANSION GLASSES.

IN a paper recently read before the New York section of the Society of Chemical Industry, Mr. E. C. Sullivan gave some figures which illustrate strikingly to what extent the expansion of glass on heating can be varied by suitable changes in its composition. Ordinary lead glass has, he states, a linear expansion coefficient of 9.2×10^{-6}, but glass can be made without difficulty having coefficients as high as 1.3×10^{-5} or 1.4×10^{-5}, that of copper being 1.75×10^{-5}, and of iron 1.3×10^{-5}. On the other hand, a glass recently produced in America has a coefficient of as little as 3.2×10^{-6}. This is being used to some extent for laboratory apparatus and culinary vessels, but is for the most part used for battery jars and lantern globes for railway purposes. This glass has practically the same coefficient of expansion as the best porcelain, with which it makes a satisfactory seal. The coefficient of expansion of quartz glass is, Mr. Sullivan states, between 6×10^{-7} and 7×10^{-7}. The low expansion glasses are often very stiff at the ordinary melting temperatures, a fault which, to some extent, can be corrected by the use of boric acid, but if added in large quantities this affects seriously the stability of the glass. One low expansion glass containing much boric acid dissolves slowly but completely in water, whilst acid will eat through $\frac{1}{8}$ in. of the glass in a few days. For some purposes, however, this glass is serviceable, and hundreds of tons have been used. A curious fact noted by the author is that when glass baking-dishes were used the baking was more rapid than when metal dishes were used. This was traced to the fact that metals reflect from 83 per cent. to 99 per cent. of the radiation incident on them, whilst glass reflects only some 3 per cent. to 14 per cent.

AMERICAN RAILROADS.

The uses of adversity are not always sweet, but they have their advantages. The economies forced on the railroads of the United States by rate reductions in the face of advancing wages since 1913 caused a decrease of operating expenses of 191,446,000 dols. in 1915, although more passengers and freight were carried. In the first half of 1915 there was a decrease from operating revenues of 11,000,000 dols., and a decrease of expenses of operation of 56,000,000 dols. It was only in the second half of 1915 that the influence of the European war was really felt on the American railroads, in consequence of the call for enormous quantities of war munitions and foodstuffs. The increase in gross operating revenues in that period was 204,000,000 dols., and this was earned without a proportionate increase of operating expenses. In the first half of 1915 the ratio of expenses to revenue was 72.02 per cent., and in the second half 63.33 per cent. Since 1907 the ratio has fluctuated between 67.7 per cent. and 72.19 per cent. The net operating income of the railways in 1915 was 899,000,000 dols., as compared with 687,000,000 dols. in 1914 and 801,000,000 dols. in 1910, the previous best year. The operated mileage of the privately-owned, government-controlled railways of the United States on June 30, 1915, was approximately 266,000 miles. Of this, 247,312 miles are single track, and 98,166 miles yard tracks and sidings, and less than 34,000 miles two, three and more track. This is an enormous length of line in comparison to the population. In Europe the ratio of population to miles of railway is 2142 to 1, while in the United States it is 406 to 1, the proportion being more than 5 to 1 in favour of the American citizen. The boom in railway traffic found the American companies quite unprepared to cope with it. During the decade preceding 1907 the railway traffic, measured by earnings, had increased over 130 per cent., and the freight tons carried 1 mile by 154.3 per cent. This last amazing increase had been handled with an increase of 100 per cent. in the weight of locomotives and 127 per cent. in the capacity of freight cars. In the eight years between 1907 and 1915 the traffic of American railways increased less than 14 per cent. This was attended with an increase of 45 per cent. in locomotive weight and 42 per cent. in car capacity, so that at no time during the period of eight years since 1907 were the facilities of the railways more than locally or temporarily taxed. Last June the railways had to provide power and equipment to meet an unprecedented rush, when factories were crowded and prices soaring. The number of freight cars in the United States is now approximately 2,500,000, and the average annual construction is 120,000. During 1915, however, there were only 74,000 cars built, in addition to 1949 passenger cars and 2085 locomotives. The result has been that it has been most difficult to get merchandise conveyed to the ports, and this difficulty has been vastly increased by the want of shipping. Cars could not be unloaded and had to be stored in sidings, until scores of miles of cars were laid up in this way, and the number available for service still further decreased. Very many interesting facts in connection with American railway working are to be found in *Railway Statistics of the United States of America*, issued by the Bureau of Railway News and Statistics, to which we are indebted for these figures.

THE MOVEMENTS OF THE EARTH'S POLE.

Discoursing on the movements of the earth's pole at the Royal Institution last Friday, Colonel Edmond Hills, R.E., D.Sc., F.R.S., Secretary of the Royal Institution, considered the problem as it affects a freely-suspended earth, quite disregarding any attractional influences of the sun and moon, &c. If the earth were a perfect sphere, he pointed out, it should, once set in rotation, continue to spin regularly about any diametrical axis. But the earth was flattened at the poles, and the rotation could only be stable if about its one axis of symmetry. Rotation about any other axis, not an axis of figure, would be unstable, and Euler taught, 150 years ago, that the axis of rotation should revolve about the axis of figure in a period, depending upon the shape of the earth and its elasticity, but not upon the actual distance between the poles of the two axes. Assuming the earth to be rigid, Euler predicted a period of 306 days, or 10 months, for this movement. The movement would become apparent in a variation of the latitude of any spot on the earth, if the latitude were determined in the usual way, by measuring the altitude of the north pole—the elevation of the pole above the horizon, which is equal to the latitude—or rather the distance between the zenith of a place and the celestial pole. Attempts to determine this variation were made, but the effect seemed to be too small for exact measurement. In 1884, however, S. C. Chandler, at Harvard Observatory, and H. Küstner, at Bonn, reopened the problem independently. Chandler observed a progressive change in latitude, irregular and not of a 10 months' period, and he was going to give up the work when he heard that Küstner had come to similar results while studying fluctuations in the constant of aberration, which he ascribed to variations in latitude. Chandler then continued his work and traced a period of 428 days (or 14 months), which, Simon Newcomb showed, would be in accord with the probable elasticity of the earth. The Geodetic Institute at Potsdam then took the matter up; and the International Geodetic Conference of 1889 resolved to entrust the very laborious work to six stations, all lying approximately in latitude 39 north (Mizusawa, in Japan; Tshardfui, in Central Asia; Carloforte, near Sardinia Island; Cincinnati and and two other stations in the United States, in Maryland and California); two more stations in the Southern Hemisphere were later decided upon. Colonel Hills exhibited some of the curves compiled by Albrecht from these international observations. They showed that the pole had been describing an irregular spiral since 1890, this spiral, which was widest at the date named (extending through nearly 0.3 second of arc to both sides of its mean position), afterwards contracting, and then became enlarged again. The excursion was exceedingly small; measured near the pole it would hardly amount to more than twice 20 ft., and would thus fall within the dimensions of a large room. Some of the best work in connection with the problem had been done in Japan, where Kimura had tried to separate the Euler effect from other, more irregular and probably seasonal effects. Colonel Hills indicated how the curve could be analysed. Seasonal effects might be due to the melting of the polar ice caps during the summer of a hemisphere; John Milne had suggested that big earthquakes might displace the pole and affect at least the regularity of the curve, but his later calculations had not supported this view. Others had thought that the solar atmosphere extended beyond the earth, and that the refraction in that atmosphere should be strongest in summer; such an atmosphere was improbable, yet some refraction effect was possible, as the analysis showed that a certain component was great in summer and vanished at the equinoxes. The ice effect looked the most likely. But more observations by special instruments were required. Chandler had attached a telescope to a platform floating on mercury; others had designed special floating telescopes, vertically mounted. Colonel Hills himself had a telescope constructed which was suspended in a pit; temperature, wind and the bending of ordinary telescopes would not affect this type, but it was subject to earth magnetism, unless entirely free from iron. The instrument was, he said, ready, but had not yet been used owing to the war.

BRAZILIAN TRADE WITH THE UNITED STATES.—We read in *Machinery*, New York, that plans are being made in Brazil for organising a commercial commission which will visit the United States, with the threefold purpose of calling the attention of capitalists in the United States to opportunities for investment in public utility and manufacturing establishments in Brazil; for increasing the exports from the United States to Brazil by showing what Brazil wants in machinery, textiles, and other manufactured articles, and by explaining Brazilian requirements in the matter of banking, exchange, customs regulations and transportation, and for increasing the imports of Brazilian products into the United States.

GLASGOW SHIPPING WHO'S WHO.—There has just been issued at 1s. net by the proprietors of the *Liverpool Journal of Commerce*, from their Glasgow offices at 105, West George-street, the fourth annual edition of this useful publication. In addition to a map of the ports of Glasgow and of the Rothesay Dock at Clydebank, there are given, alphabetically arranged, Glasgow shipowners, with the names of the officials and the fleets, and of Clyde shipbuilders, ship-repairers and engineers, also with the names of their officials, and particulars of the capacity of the works. Railway facilities, officials of marine technical and commercial organisations and the like have similar treatment, while a full personal index enables one to ascertain the connection of individuals with the shipping interests of the city and river.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—We have received a copy of the revised Regulations and Syllabus for the examinations held by the Institution of Municipal and County Engineers. Candidates will now be admitted to the examination at the age of 21 instead of 22. Candidates will be required to have spent at least a year in the office of an engineer engaged in public work. By the elimination of a certain amount of overlapping and re-arrangement it has been possible to reduce the number of papers by one, which together with the addition of an extra day to the examination has given an opportunity of instituting a practical examination. The practical examination will be supplementary to, and not in substitution for, the *viva voce* examination; it is hoped that examination of candidates on the actual site on which work is taking place will result in establishing a still higher standard of practical ability and knowledge than has hitherto been obtained. There is also an examination for the Certificate in Town Planning and in County and Highway Engineering.

EXPLOSIBILITY OF ACETYLENE.—Acetylene being extensively used as an illuminant for miners' lamps in the United States, the Bureau of Mines (Technical Paper 112, by Messrs. G. A. Burrell and G. G. Oberfell) investigated the explosibility of acetylene-air mixtures, experimenting, as in previous investigations of a similar kind, in a Hempel pipette of 100 cub. cm. and in a large vessel of 2800 cub. cm. Ignition was produced in the former case by passing a spark between two platinum-wire electrodes, and in the latter by pulling apart two copper wires carrying current of 5 amperes at 220 volts. The lower limit of explosibility was found to be 2.81, or 3 per cent. of acetylene, the upper limit 73 (in some cases 50) per cent.; the latter figure fluctuated strongly with the experimental conditions. Compressing the mixture had little influence, however. But when acetylene itself (not mixed with air) was compressed, it was exploded by a heated platinum coil when at five atmospheres pressure, and by an induction coil at three atmospheres pressure. The investigators made some calculations to show that little danger should arise in mines from calcium carbide coming into accidental contact with water or being exposed to moist air. But they admit that one accident has occurred: A miner carrying calcium carbide in a glass bottle stumbled, the carbide fell into a pool of water, and the acetylene generated was ignited by his cap light, severely burning the man.

INDUSTRIAL NOTES.

THE President of the Local Government Board has brought the following to the notice of Tribunals on the subject of skilled workers useful for munitions-work but not badged. In some cases, especially in the case of unmarried men under (say) 25 or 30 years of age, the Tribunals may not think it necessary to issue a certificate of exemption in respect of the private work upon which such workpeople are engaged; and the question will then arise whether they possess qualifications specially required for munitions work. Where this is the case, the national interest will probably best be served by making the issue of the certificate of exemption conditional upon the applicant's obtaining work entitling him to wear a War Service Badge within a month, or such longer time as may be necessary to enable his badge to be issued. The occupations for which there is at present a most urgent demand for munitions work for men of all ages are the following:—Millwright; fitter and erector (engineering); turner (engineering), excluding capstan and automatic lathe turners; planer (engineering) who sets up his own machine; slotter (engineering) who sets up his own machine; miller (on universal and slab machines) who sets up his own machine; grinder (on precision grinding machines); sheet-metal worker (engineering); marker-off (fitter, turner and draughtsman only); draughtsman (engineering, not tracer); coppersmith; examiner (fitter or turner only); viewer and gauger (fitter or turner only); tool setter for machine tools; tool fitter. In the case of these occupations Tribunals will be justified, after satisfying themselves of the occupation of the man, in granting conditional certificates of exemption, in the manner described above, without further inquiry.

Retail food prices in the United Kingdom, says the Director of the Department of Labour Statistics, showed an increase of about 4 per cent. in April. As compared with May 1, 1915, the general level of prices showed an increase of about 23 per cent. Taking the country as a whole, and making allowance for the relative importance of the various articles in working-class household expenditure, the average increase in the retail prices of food since the beginning of the war may be put at 55 per cent. This figure relates to food only, and in estimating the increased cost of living this percentage must not be applied to the total family expenditure, but only to that proportion which is expended on food.

During March an increase amounting to 8 per cent. was recorded in the general level of retail prices of certain of the more important articles of food in Berlin as compared with February, while retail food prices as a whole rose to 100.5 per cent. above those of July, 1914. In arriving at these results allowance is made for the relative importance of the various articles in working-class consumption. As compared with July, 1914, every article was dearer, the general result being that the retail cost of a fixed scale of food consumption would in March, 1916, have been just over twice as much as in the last month before the war. As an index to the state of food supplies in Berlin, detail figures of cost can only be accepted with reserve. The prices recorded are in several cases maxima, above which retail dealers are not legally permitted to charge. Moreover, many articles may only be sold in strictly limited quantities; while others would appear to be unobtainable at the ordinary shops.

In March a scarcely perceptible rise (0.1 per cent.) was recorded in the general level of retail food prices in Vienna, but in comparison with July, 1914, that level showed a rise of 110.4 per cent. As an index to the state of food supplies detail figures, like those relating to Berlin, can only be accepted with reserve, since many of the most essential kinds of food are no longer sold in a free market.

According to the journal of the Swiss League for Reducing the Cost of Living, the general level of retail food prices in Switzerland in March, 1916, showed a rise of 2.7 per cent. since December, 1915, and a rise of 29.9 per cent. as compared with June, 1914.

The Scottish Coal Trade Conciliation Board Meeting in Glasgow on Tuesday considered the miners' application for an advance of 1s. per day in wages; and, failing to come to an agreement, decided to ask Lord Loreburn to act as neutral chairman.

A conference was held on Tuesday in the Glasgow offices of the shipbuilding and engineering employers between representatives of the North-West Engineering Trades Employers' Association and of the Clyde District Committees of the Amalgamated Society of Engineers to consider the application of the men for an advance of wages. The advance asked is 2d. per hour on present rates. Since the war began the Clyde A.S.E. men have made two previous applications for advances of wages on their own account, and one jointly with the other unions represented on the Federation of Engineering and Shipbuilding Trades. In August they obtained an advance of 1d. per hour as a result of one of their individual applications. The conference failed to arrive at any decision, and it is expected that the application will either be carried to a Central Conference between the Engineering Employers' Federation and the Executive Council of the A.S.E. and afterwards to the Government Committee on Production, or to the Committee on Production direct.

In the course of an address he delivered in Glasgow on Tuesday, the 16th inst., Mr. T. C. Elder, of the British Electrical and Allied Manufacturers' Association, stated that there was a very natural and excusable reluctance to resume the wearisome debate touching Free Trade and Protection if it could be avoided. But the war had sharply reminded us of the need for discrimination and selection in our ways of earning our national livelihood, and the country was ready to accept in place of all-round Free Trade or Protection some rational system of public encouragement for those trades that appeared to be of most vital importance. The idea of industrial preference suggested first consideration for three groups: the agricultural, the textile, and the engineering, which included shipbuilding. What we were concerned with was the engineering group, and we base our claims on three propositions:—

1. National and Imperial safety depended on the maintenance of a progressive and prosperous engineering industry. The decisive influence of machinery in warfare became more and more marked, and we could not again take the risk of allowing Germany to attain mechanical military superiority on land or sea, or under the sea, or in the air. All possible public support should be given to the technical advancement and the commercial organisation of British engineering as a question of life and death.

2. Engineering was in peace also the key industry. Machinery was universally employed, and in agriculture, in manufacturing, and in transport efficiency and prosperity depended on the prompt adoption of modern equipment. The existence of a great engineering industry in Britain was an obvious advantage to general productive occupation. If we kept Great Britain a well-engineered country we were going far to ensure that it would be a well-populated, a well-capitalised, and a well-employed country.

3. The national earning power of this group of industries could be greatly increased by taking intelligent advantage of its extension and improved equipment due to the demand for munitions, and by collective exploitation of foreign markets by associated manufacturers and financiers.

Here, then, was surely an industry which was entitled to preferential consideration. Whether engineering should have special State encouragement had no dependance on a general change of British fiscal policy. Free Trade in some other descriptions of manufactures might still be left as a debatable question. Free Trade in engineering must go for ever. To go on employing Germany to make machinery for us; to allow her syndicates to corner our metal supplies; to give her equal opportunities of developing her engineering and shipbuilding as though these were purely peaceful industries would be a political crime. It would be an insane gamble with the primary interests of our country and our Empire. It would be an infamous betrayal of those who have shed their blood in our defence. It would be an abject surrender of all that they were fighting for, because we could not guarantee to guard our own liberties and to fulfil our duty of maintaining the independence of the smaller nations if we again allowed this enormous mechanical power to be wielded by those who had proved themselves the world's leading exponents of scientific savagery.

The representatives of the coalowners and miners for the Federated districts of England and North Wales, at a meeting of the Coal Conciliation Board held in London on Thursday, the 18th inst., agreed together upon an advance of 3½ per cent. on the present rate of wages, to take effect from the second pay day in June. The decision governs the wages of 350,000 men and boys.

On Thursday, the 18th inst., a deputation of coalowners of the United Kingdom met, at his request, Mr. Runciman, President of the Board of Trade, with a view to discuss a scheme for limiting the price of coal exported to France. The meeting was private, but it is understood that the deputation agreed in principle to a voluntary limitation of the price of coal, and that steps will be taken to put the matter before the various districts and to formulate at an early date a definite proposal for the consideration of the Board of Trade.

The Federation of Engineering and Shipbuilding Trades held meetings last week in Aberdeen. The proceedings were private, but it was officially announced that the questions which were discussed referred to overtime and to dilution of labour in shipyards. There was also considerable discussion on a proposal by the Admiralty which had been endorsed by the Munitions Central Labour Supply Committee, to the effect that in order to prevent unnecessary time-losing no overtime should be paid for unless the standard number of hours each day had been worked, due regard being given to cases where time was lost through causes over which the workmen had no control. It was not proposed to apply this regulation to repair work or to shipyards in which it was the custom to pay overtime after a full week had been worked. The proposal of the Admiralty was strongly objected to by the representatives of the shipbuilding trades, and a resolution was accepted declaring that it was not calculated to increase the output and urging the trade unions to assist in meeting the nation's requirements by working full time and by curtailing the holidays. In regard to an advance in wages, it was decided to ask the President of the Board of Trade and the Minister of Munitions to receive a deputation for dealing with the question of State regulation of the prices of the commodities of life, the meeting being of opinion that such a resolution was much more important and would be much more beneficial than an advance in the present rate of wages. A proposal to increase old-age pensions to 10s. per week, sent in from the Tyne and Wear District Committee, was agreed to unanimously.

The Minister of Munitions announces that he has made further orders under the Munitions of War Acts, 1915 and 1916, under which 131 additional establishments have been declared controlled establishments. The total number of controlled establishments under the Munitions of War Acts, 1915 and 1916, is now 3577.

Writing in the sixty-seventh quarterly report, dated March, 1916, of the General Federation of Trade Unions, Mr. W. A. Appleton, the Secretary, states that the quarter just ended sees a further addition to the Federation's reserve fund of more than 15,000*l*. Contributions have risen a little, and the amount paid in benefits is down by about 80*l*. The additions to reserve, though substantial, are not in excess of possible after-war requirements. Opinions differ as to the nature of after-war problems and their effect upon the trade union movement; but there ought to be no difference of opinion about the need for proper preparation and substantial banking accounts. During the period of industrial and commercial readjustments which will follow the signing of peace, the fate of movements as well as nations will be decided. Trade unionism must not depend upon promises or hope to receive preferential treatment; it will secure just what it is strong enough to take, that and nothing more. Such a statement does not imply criticism or any charge of breach of faith; it is just a statement of fact and is based upon historical and economic experience. It is therefore of profound importance that trade unions should decide at once what they want; how far their wants are within the bounds of possibility; and then what kind of organisation and how much money is needed to win through. National exigencies have resulted in the more drastic application of income-tax regulations. Organisations as well as individuals have been rounded up.

THE GERMAN PETROLEUM INDUSTRY AND THE WAR.—The German Petroleum Company has done exceptionally well, owing to the war, in the year 1915, and could easily have declared a higher dividend than the 20 per cent. which the shareholders now receive (against 12 per cent. for the preceding year), the working profits from all works and affiliated concerns, which are not specified in the report on account of the war, amounting to about 30,000,000 marks (1,660,000*l*.), against 9,200,000 marks (510,000*l*.) for 1914. Whilst in times of peace the business done by the German Petroleum Company is materially less than that done in imported American petroleum, especially through the German American Petroleum Company, the former in 1915 had to supply the bulk of what Germany needed. This necessitated a number of new installations, which may not all be wanted in times of peace, wherefore liberal writings-off have been provided, 2,360,000 marks against 850,960 marks in 1914 on home concerns, and 6,000,000 marks on the Austrian petroleum works and refineries. This large sum has been written off on account of the company's relations to the Premier Oil Company, which controls the principal Austrian interest in the concern. After all the writings-off the surplus exceeds 12,000,000 marks, against 6,541,982 marks in 1914. The dividend (20 per cent.) absorbs 6,150,000 marks, 1,277,777 marks are added to the reserve (now 10,000,000 marks), 2,000,000 marks are to form a building reserve, with a view to the new works at Schöneberg, 1,000,000 marks go to a fund in aid of officials and workmen, and 1,000,000 marks to a national institution, a sum of about 2,350,000 marks having been left over from the previous year's profits. For the war-profit tax a reserve of 6,500,000 marks had already been deducted from the gross profits. The company's holdings of State securities, exclusively German and Austrian war loans and Bulgarian loans, at the end of December, 1915, amounted to 9,624,000 marks but since then 12,000,000 marks have been subscribed to the fourth war loan.

"INDUSTRIAL DEVELOPMENT."

TO THE EDITOR OF ENGINEERING.

SIR,—I am sure that all who heard or who have read Mr. Harold Cox's address upon "Industrial Development," delivered by him to the Institution of Civil Engineers on March 7, 1916, must agree with his criticism of the Consular Service, and the futility of the *Journal of the Board of Trade*; also with his conclusion that the manufacturers of this country, whether of the engineering or other trades, can expect no help from such an office, but must combine to further the interests of national trade abroad by forming a "National Trade Agency" themselves. This incitement to "collective effort" is in the right direction, but I venture to think that Mr. Cox's proposals do not go far enough; and it is the purpose of this letter to indicate how much farther I think they might be carried. We are suffering from having overstrained the national principle of individualism, and must modify our methods in accordance with the signs of the times.

Individualism has its merits, but the conditions of war strikingly illuminate its defects, and I think it does not require a very lengthy analysis to show that the dangers which threaten our commercial and domestic welfare are due to the results of this overstraining of a principle which has done good service in its day, but is failing us now under altered conditions.

The tendency of all commercial undertakings is towards the amalgamation of capital in huge limited liability companies or trusts, to the extinction of the private trader. This results in destroying the old personal relationship between master and man. A rigid and impersonal relationship is in consequence set up between capital and labour. This further leads to the segregation of employers and employed. The employers flock to one quarter of the town, or distant houses in the country; the employed are left in congested districts of population without the humanising and civilising touch of any refinement in their midst. Destruction of any spiritual unity is the result. This is the domestic danger.

On the other hand, the tradition of absolutely unfettered competition has left the employer under a Government which has adopted the principle of *laissez faire* as its guide in a position of precarious isolation. When he meets the delegates of a strong trade union, who can declare a strike at will if he conform not to their rules, he is practically helpless. Even when, as a counterpoise, he forms an employers' federation, his position is not much bettered. The mutual jealousies of competitors make all their proposals timid and half-hearted, and the balance of advantage in the conferences which take place generally leans to the trade-union representatives, who know better what they want and are more direct in their policy, because they are pleading for a united interest against a divided one. Recent legislation has still further strengthened the position of the trade unionist. When politics enter into trade disputes, the old principle of *laissez faire* and unrestricted competition breaks down.

It seems to me impossible to go back to the conditions which made it possible to treat a trade dispute as a domestic one between the individual employer and his shop hands. We have got to accept modern conditions, and make the best of them; and the only way to make peace between capital and labour, and assure prosperity to the trades in which they are both engaged, is to make the State the protector and arbitrator of both.

It may be objected that the laws of the State already provide for this. Unfortunately the power of the vote weighs down the scales of justice unfairly, and so far as legislation has adopted the principle of State interference it has been hitherto all in favour of labour. The limit of safety in this direction has been reached, and, in the opinion of many, overpassed.

Capital is a plant of slow growth, and owing to the fact that its roots are in the soil, or at any rate in the plant on the soil of a country, it is not so mobile as labour; but if it should be driven by discouragement to another country, it would be all the more difficult to replant it in the country it has left: and labour, while it is mobile in its own country, is generally timid of the transplanting operation called emigration, and would suffer more acutely by the dwindling resources of its nation, because its own resources are less. The parable of Menenius Agrippa still holds good.

On the other hand, the attitude of the trade-union leaders under the stress of war has been admirable, and inspires the greatest confidence in their political acumen among their fellow countrymen. The strikes which have disgraced the generally patriotic attitude of labour since the commencement of the war have been contrary to the advice of the trade-union officials. They are an illustration of the danger to which our traditions of individualism expose us. But it would not be fair to place the responsibility for these manifestations of ignorance on the shoulders of the leaders of trade unionism. There are men among them of the greatest ability, and from personal contact I can give my homage to Mr. Arthur Henderson as an outstanding and brilliant example of this.

Here then may be found the material with which to build the strong fortress of collective effort by the true conciliation of capital and labour, between whom they may act as mediators, as the cement of unity.

The time, as Mr. Cox shows, is propitious. Men who have fought shoulder to shoulder in the trenches, men who have sacrificed many of their cherished trade privileges in the workshop for the sake of the ideals for which we are fighting, are surely in the mood to listen to the voices of conciliation and propitiation, to make our national position stronger in peace, when it comes, than it was before it was broken. To prove my point I must hark back to the conditions in industrial development existing a generation or two before the outbreak of this war.

Within my own recollection, the relations between master and man were personal and patriarchal. The master had been trained at the same bench, forge and moulding-floor as his hands. When he succeeded to his father's place in the business, he was intimately acquainted with the domestic conditions as well as the personal skill of his employees, and knew not only the fair time to allow for the completion of a job, but the deficiencies of the particular workshop in which he was brought up. If he was a wise man, he did his best to ameliorate the conditions of his workmen, at any rate during their working hours. He improved the lighting, heating, cleanliness and sanitation of his shops, as well as the labour-saving efficiency of his plant. These improvements did not prevent strikes, but they took off the edge of bitterness from the disputes.

The growing political power of the trade unions compelled the masters to combine in their turn, to form defensive associations; the growing intensity of competition forced the smaller firms to amalgamate with larger ones; the patriarchal traditions of the old school were forgotten in these huge combinations of capital, and the jealousy and suspicion of the workman against his employer was deepened and embittered. Thus the domestic side of industrial development under pre-war conditions was giving every thoughtful citizen the keenest anxiety, especially those who were responsible for the technical efficiency and financial stability of their own trades.

I now appeal to this latter class, the capitalist class, to come forward, forgetful of their old antagonism to trade unionism, and find a *modus vivendi* under which the first condition of industrial development—viz., industrial peace—can be secured.

I offer the following suggestion to begin with—viz., to put their general and technical intellectual acquirements at the disposal of the trade union of their particular trade, to assist them in forming a board of examiners who would test the fitness of the apprentices to skilled occupations by periodical examinations in their practical and theoretical progress. To acquire, further, a statutory right for such boards to issue certificates for various degrees of efficiency, such as journeyman, leading hand, foreman, draughtsman, leading draughtsman, and works manager, on similar lines as the Board of Trade examinations for merchant seamen.

The trade-union officials would form at least half of such examining boards, and by their practical experience would devise the scale of practical tests. The representatives of the employers would undertake the scientific and higher technical tests, and in the engineering trade I submit that the Institutions of Civil and Mechanical Engineers could provide from their members the best qualified examiners, who have themselves been through the tests devised by those Institutions. I venture to think this would be a big step in developing the efficiency of the trades concerned, and the degrees so granted should carry with them in their own trade the same weight as a university degree does in the learned professions.

I should further hope that such an alliance between the employers and the trade unions, for the benefit of the technical efficiency of their particular trade, would ultimately lead to the establishment of industrial peace by merging employers' associations with trade unions on a basis similar to that of the old Guilds.

From my experience of the conferences held between these two bodies in the engineering trade, I am sure that my suggestion is a practicable one, and would go far to obliterate those class suspicions which Mr. Cox so rightly deplores.

To get out of the old, bad groove it must be upon the generation now entering manhood that we must try this experiment. The trade-union officials, whose purview has been enlarged by the tremendous international conflict now going on, and the employers, who have had to sacrifice so large a share of their profits to the State in its peril, are in a fit moral state to make the *amende honorable* to one another, and coalesce for the benefit of the State in the trying time that we may expect upon the conclusion of peace. This is a reform which requires immediate attention. But there are others of a more constructive nature than this readjustment of domestic trade conditions, which I desire to indicate from the broader outlook of national prosperity, and which are at the same time bound up with the commerce upon which we live.

This is a subject which I trust you will permit my dealing with further in a later issue.

Yours truly,
VENATOR.

LABOUR EXCHANGES AND TECHNICAL STAFF APPOINTMENTS.

TO THE EDITOR OF ENGINEERING.

SIR,—We should be pleased if you would insert this letter, which is written in full support of the opinion expressed in the letter from "Two Interested Engineers" upon the above subject.

From the point of view of both advertisers and applicants, the situation is intolerable, for apart from the fact that the manager of a Board of Trade Labour Exchange is not qualified to judge the suitability of an applicant for any engineering staff appointment, we know for an undoubted fact that the majority of qualified men hesitate to reply to these advertisements, from a disinclination to having their past experience and career laid bare to the petty officials of the local Labour Exchange, with the minimum chance of success, as a result of their application.

A further point to be considered is that where an applicant is already engaged in a controlled establishment only partially on war work, even if his application were not turned down by the labour exchange, as suggested by your correspondents, he is usually requested to forward a certificate from his employers, stating that they would release him, before his application will be considered. For obvious reasons this cannot be obtained, with the result that in these circumstances one is precluded from applying for an appointment perhaps more suitable for the abilities of the applicant than the position he holds.

The net result of this method of advertising is that the field of applicants is very much reduced, and we thoroughly concur with your correspondents in their statement that the country does not benefit, as was presumably intended by the Government.

Yours faithfully,
THE TECHNICAL STAFF OF A LARGE ENGINEERING WORKS.

May 22, 1916.

TO THE EDITOR OF ENGINEERING.

SIR,—Whilst heartily endorsing the opinions of the correspondents who have written you as to the disadvantages, from the employer's point of view, of filling technical staff appointments through labour exchanges, may I draw attention to another side of the question? That is, that by attempting to fill these places through the labour exchanges, employers are depriving themselves of the applications of many of the best and most likely people, who will not register at a labour exchange, and submit themselves to be examined as to their fitness for any particular post by (often) a very "superior" young man, who knows nothing whatever about engineering or the qualities necessary to the adequate discharge of the duties of an engineer or a draughtsman.

The same remark applies also to the commercial staff appointments.

Yours truly,
F. T. H

Manchester, May 22, 1916.

TO THE EDITOR OF ENGINEERING.

Sir,—Being also "interested," I fully appreciate the letters referring to this subject in the last two issues of ENGINEERING. My interest and experience come from the foundry side of engineering and the appointment of managers and foremen to such departments.

How it is possible for a labour exchange manager to be the determining factor in any application for such a position is beyond comprehension. Another point: how can any card system, or any number of cards of particulars, convey the matter concerned compared with a letter? I will relate two of my experiences with the exchanges. I applied for a post through your paper c/o Labour Exchange. My letter was held up for inquiry, because I had given the name of an engineering firm of high repute, for whom the foundry I was employed with made the castings, the engineering firm cited having no foundry, yet, though a local concern, this was not known to the exchange officials.

On a more recent application I required to verify the number of the advertisement, and went to the exchange for that purpose. In doing so I gained the information where the job was, but was informed I must not write the firm direct. With this I complied. About five weeks later I received the official communication that I had not been successful, and with this my letter of application was enclosed. This seemed to me very strange.

In the meantime an advertisement, similarly worded, appeared in another journal, replies to be directed to Box—. As much out of curiosity as anything else, I wrote exactly a similar letter. A fortnight after receiving my letter from the exchange I had a reply from this last advertisement, and, strange to say, from the very firm quoted by the exchange clerk. I have since had an interview and am at present awaiting a reply. This may be a coincidence, but it shakes one's faith in any letter going through such channels having the best results. What do interested employers think about such matters?

Thanking you in anticipation of your inserting this letter and also the previously "Interested" for opening the ball.

Yours respectfully,
INTERESTED FOUNDRYMAN.

"THEORY AND PRACTICE IN THE FILTRATION OF WATER."

TO THE EDITOR OF ENGINEERING.

SIR,—Our attention has been called to a paper by Mr. Walter Clemence published in your journal, and to correspondence respecting the same, and we shall be greatly obliged if you will permit us to correct some errors which we think are calculated to mislead such of your readers as do not make a special study of water purification.

The term "rapid filtration," as used in connection with water purification, is now generally understood to mean the triple process of coagulation, sedimentation and filtration; and rapid filtration without coagulants is usually termed "roughing filtration." Mr. Clemence uses these terms indiscriminately in a misleading manner.

In his opening remarks he states it is obvious that if purification is imperfect in a slow sand filter when exceeding a certain speed, it must be more so in a rapid filter. It is difficult to believe that this statement is merely intended to assure a body of engineers that roughing filters are more imperfect than slow sand filters, but it is even more difficult to believe that it is intended to imply that rapid filters, as the term is usually understood, cannot safely be operated at greater speeds than slow sand filters. Nor is it correct, as stated later, that little or no reduction of bacteria is effected by rapid filters used as roughing filters. It is true that the results of roughing filters are unreliable, and show a wide range of variation; but there are plants in use removing an average of over 80 per cent. of bacteria.

There are in the United States alone rapid filters

having a daily capacity of over 1,770,000,000 gallons, which supply over 40 per cent. of the population, whereas slow sand filters supply only 16 per cent.; it is therefore difficult to understand what Mr. Clemence means by stating that "it is rare to find high-speed filtration relied upon as a single line of defence against water-borne diseases." The remark is the more inexplicable as even if ignorant of work in America, we think he cannot fail to be aware that we have constructed in Egypt alone a number of plants having a daily capacity of over 32,000,000 gallons, which are being solely relied upon for the treatment of the badly polluted Nile water. It is also remarkable that although in India we have plants treating municipal supplies having a daily capacity of over 12,000,000 gallons, Mr. Clemence selected for criticism a small filter of under 300,000 gallons capacity, treating a sewage-polluted spring water. To those familiar with water purification problems the selection is particularly eloquent, especially as there are numerous rapid filter plants throughout the world in which daily records are kept, and about which information could no doubt have been obtained had Mr. Clemence been desirous of impartially stating the facts. It would be idle to deny that imperfections occur in all systems of water purification, slow sand beds, rapid filters, and even multiple filters. We are informed that at one time serious trouble was experienced with the multiple filters at Magdeburg, and also with those in India, and it is well known that those in Derbyshire do not remove the colouring matter, and that subsequent treatment is thought desirable.

We mention this, not because we wish to infer that multiple infiltration, or even these plants, are therefore unsatisfactory, but as a reason why in a paper reputing to give an impartial survey of the subject, delivered to engineers for their information, the conclusions in favour of multiple filtration would have been more convincing had the author displayed more modesty in his claims, and exhibited less bias in dealing with other methods.

Public health statistics are the best evidence as to the reliability of different systems of purification, and although there is naturally a larger volume of evidence in favour of the much older slow sand filters, there is an ever-growing volume to show that rapid filters are equally or even more efficient, and in at least one important town, where slow sand filters have been replaced by rapid filters, there has been a marked improvement in the public health.

After the public health records, evidence as to reliability in removing bacteria is most important, and here again there is a mass of evidence to show that rapid filters are equally as reliable as slow sand filters.

Apart from these practical results, there is a mass of evidence derived from elaborate experimental investigations that have been made both in America, Alexandria, Berlin, and elsewhere, which have been published for the benefit of engineers, and it is therefore difficult to understand why Mr. Clemence has chosen to ignore these data.

We should like to refer to Mr. Clemence's doctrine of purification by nitrification. A very eminent chemist, in dealing with this subject, asked "What possible sanitary significance is the mere organic matter, whether animal or vegetable, in the absence of specific germs of disease?" Eliminating the æsthetic phase, and the possible effect of imagination on the human organism, it actually has very little sanitary significance, as he proceeded to show later in dealing with this subject. The quantity of dissolved organic matter in most potable waters is infinitesimal, and although prior to the discovery of bacteria its presence was thought to be of considerable significance, it would be interesting to hear in what manner it is now thought to be injurious. In many important slow sand filters it is impossible to find any evidence of nitrification: in all the effect is a mere trace. As, however, it is well known that all filter plants effect a reduction of what may be termed dissolved organic matter, it would be of academic interest, although of no practical value, if Mr. Clemence could give figures showing the increase in nitrates due to multiple filtration.

We regret to notice a revival of the foolish claim that slow sand filtration is a natural process, and rapid filtration an artificial one. It is true that in many respects slow sand filtration is dependent on natural conditions beyond the engineer's control, but this is not, we presume, what Mr. Clemence means. Perhaps it is intended to infer that multiple filters are a natural phenomenon. The statement that the efficiency of slow sand filters is due to the presence of nitrifying bacteria, and that the algæ and plankton are detrimental, is, we think, a gratuitous assumption entirely unsupported by the observed facts.

Finally, we are of opinion that the value of Mr. Clemence's paper would have been greatly enhanced if he had given complete chemical and bacteriological data for the several filters, from which engineers could have drawn their own conclusions. These would probably have shown whether or not this system is more reliable than attempts made years ago to obtain nitrification by intermittent filtration.

Yours faithfully,
FOR JEWELL EXPORT FILTER COMPANY,
JOHN BRETT.

8, Lendal, York, May 22, 1916.

TO THE EDITOR OF ENGINEERING.

SIR,—Had Mr. Clemence entitled his paper "The Puech Chabal System of Multiple Filtration," and confined his remarks to the experience gained in superintending their installation, the occasion for my letter published in your issue of the 12th inst. would never have arisen; but when he, while ostensibly taking an impartial survey of "Theory and Practice in the Filtration of Water," dwells at great length on the virtues of multiple filtration, and adversely criticises every other system, he must not become unduly heated if his challenge is taken up, nor resent the adoption of the same medium of publicity.

Replying to the points in my communication which he has chosen for "correction in important particulars": It is immaterial to the point at issue whether the fine silt referred to came direct from the Ganges or from a canal connected with that source.

In replying to the discussion, Mr. Clemence said: "With regard to the tables of total solids at Cawnpore, it would be better, perhaps, if I used the words "silt by weight test.'" What justification then has he for objecting to my reading these tables in the sense in which he clearly intended they should be read—viz., that the total solids given represent "silt by weight"?

Filtration which only results in the increase in the "total solids" or "silt by weight" (Mr. Clemence would like us to regard these terms as synonymous) in what he describes as "one of the purest river waters in the world" serves no useful purpose.

A 99.9 percentage reduction (no matter how obtained) of a grossly polluted water might still leave a large number of dangerous germs in the filtrate. Rapid filtration and sterilisation has proved so far to be the most effective method of dealing with such waters in India and elsewhere.

I am, yours truly,
WM. PATERSON.

India House, Kingsway, May 23, 1916.

SOME EXPERIMENTS IN LUBRICATION.

TO THE EDITOR OF ENGINEERING.

SIR,—I subjoin a short account of some experiments I lately made on bearing lubrication. As everyone to whom I have mentioned the matter thought the idea both new and interesting, I hope that you may see fit to publish it in the hope of its being useful to engineers.

The theory of a properly lubricated plain bearing requires a continuous film of oil between the moving parts. If there is no metallic connection between the shaft and bearing, it should be a simple matter to detect the oil film by the resistance it offers to an electric current. A few experiments along this line seem to indicate that a measurement of the resistance offered by the oil film is a delicate index of the lubrication of the bearing. They are here described in the hope that they may lead to further study of the subject.

A milammeter and resistance box were connected through the bearing to a dry battery. The resistance was adjusted to give full deflection of the instrument when the bearing was short-circuited. Any resistance of the oil would cause a less deflection, and the unknown resistance could then be roughly measured by substituting a known resistance from the box till the same reading was obtained with the bearing cut out.

The first experiment was with two flat surfaces separated by an oil film. A circular brass disc, 2 in. in diameter, was rubbed over a polished cast-iron plate. With a fairly heavy oil the resistance as shown by the deflection of the meter varied with the pressure applied from 0 to 100 or more ohms. The instant at which the film was broken could, of course, be detected by the increased friction, and showed at once on the ammeter. Thin oil decreased the resistance of the film, as was to be expected. Sudden changes in the resistance took place when the plates were left untouched. If left in contact, thin sperm oil separated them after a few minutes, and reformed a continuous film. At times the film was very sensitive to slight vibrations, and even sounds changed the resistance.

Another experiment was made on the bearings of an ordinary grinder. The bearings were 2 in. long, with a ¾-in. shaft turning about 1500 r.p.m. The circuit between the shaft and base put the two bearings in parallel. When at rest there was no continuous oil film, and no resistance. On starting the resistance was variable, but at full speed there was a fairly uniform resistance of about 30 ohms for the two bearings in parallel. This resistance was lowered by increasing the load on the bearings, but never reached zero.

Many other tests were made, with the expected result that well-lubricated bearings always showed a considerable electrical resistance, varying with the oil used, the speed of the shaft, and the condition of the wearing surface. Bearings under excessive load, badly fitting boxes, or deficient oil, showed a short-circuit, and heated after a longer or shorter run. The resistance test proved to be much more delicate than the usual test of heating, perhaps too delicate for some purposes. It may, however, be useful in experimental work, and in connection with high-speed machinery.

I am, sincerely yours,
ALFRED V. DE FOREST.

Hartsdale, N.Y., U.S.A., April 23, 1916.

THE PHYSICAL SOCIETY OF LONDON.

At the meeting of the Physical Society of London, held on May 12, 1916, at the Imperial College of Science, Professor C. V. Boys, F.R.S., President, in the chair, a paper entitled "*The Latent Heats of Fusion of Metals and the Quantum Theory*" was read by Dr. H. S. Allen.

The latent heat of fusion is identified with the energy necessary to counterbalance that of a certain number of "oscillators" concerned in holding together the crystalline structure. Assuming that the energy of an oscillator having a vibration frequency ν is :—

$$R T \times \frac{x}{e^x - 1},$$

where x stands for $h\nu / R T$, it is found that the atomic heat of fusion of a metal can be calculated with fair accuracy by the formula :—

$$A L = c N R T \times \frac{x}{e^x - 1}.$$

Here A denotes the atomic weight, L the latent heat, and c the ratio of the number of oscillators in question to the number of atoms. Thus the number of oscillators in 1 gramme molecule is $N c$, where N is Avogadro's constant. It is found that to the factor c must be assigned a value which is either unity or a simple fraction. The frequency at the temperature of the melting-point is calculated by means of the formula of Lindemann. The application of Debye's theory is also discussed.

Discussion.—Dr. R. S. Willows agreed with Dr. Allen that the quantum theory was still in a very speculative state. He referred to the statement in §1, that "The energy supplied to melt the solid may be identified with the work that must be done to break the bonds which impart to the solid its crystalline structure." This seemed to rule out of consideration the case of amorphous solids. It is supposed that some of the alterations produced in a metal by treatment, such as rolling, are due to some of the molecules becoming amorphous. Could the theory be extended to deal with the change from the crystalline to amorphous states?

Dr. Allen thought the change from crystalline to amorphous conditions was the same as from crystal to liquid.

Professor Boys: Would not that imply that there was no latent heat in amorphous material?

Dr. Allen agreed that that would be implied.

A paper entitled "*Lenses for Light Distribution*" was read by Mr. T. Smith.

The principle on which lenses for securing a required distribution of light from a given source have been designed is illustrated by a two-dimensional example. The principle employed is to divide the incident and emergent energy into a number of equal parts, and compute the lens system so that the rays which separate off these portions of incident light from one another are refracted as rays which separate the corresponding portions of the emergent light. The surfaces obtained are in general of varying curvature, and the lenses must therefore be moulded. It is shown how the effect of the finite size of the light source may be determined.

Discussion.—Mr. R. S. Whipple asked how the results obtained with lamps designed on the lines discussed in the paper compared with those previously employed, which had been evolved, he presumed, simply by the survival of the fittest. Were lenses of this type used as first cast or were the surfaces finally worked?

Mr. Smith stated in reply that the lamps previously in use gave very unsatisfactory results. Their performances varied greatly among themselves, and there did not appear to be any principle underlying their design. In many cases the lenses were not even symmetrically made, and the number of dioptric elements employed depended entirely on the whim of the maker. Some of these lenses had been ground, but he was not aware that they had been used except by the Admiralty. The new lenses, on the other hand, were giving very satisfactory results, despite the fact that some manufacturers had not yet quite realised the ideal conditions. The lenses were moulded and then, in some cases, glazed by what he believed was a secret process.

A paper entitled "*The Choice of Glass for Cemented Objectives*" was read by Mr. T. Smith. The strict fulfilment of the mathematical conditions for freedom fromr colour, spherical aberration and coma, for objects at varying distances from a thin cemented doublet lens, necessarily demands a change in the kinds of glass as the position of the object is changed. The paper describes a method by which the proper glasses can be determined by using a glass chart on translucent paper, in conjunction with diagrams calculated for the purpose, as a slide-rule. With most glasses the solution to the problem is imaginary, and formulæ are given for calculating the boundary separating real and imaginary solutions by solving a quadratic equation. In practice it is found that the curves for all real images lie very close to one another. Notwithstanding this, a numerical example shows that there will be a perceptible difference in the definition obtained if in place of the theoretically necessary type a kind of glass is substituted which does not differ greatly from the other, and lies on a curve giving perfect correction for another real magnification. It is further shown that when no real solution is forthcoming for a double lens a real solution will in practice be obtained by adopting a triple objective made of the same glasses.

MESSRS. BURMEISTER AND WAIN.—The year 1915 has, on the whole, been very favourable for Danish shipbuilding and engineering, and in several instances has far outdistanced the results of previous years. The Burmeister and Wain's Shipbuilding and Engineering Company's profits for last year are double those of the preceding year, which had hitherto been their best. The report states that the demand for large motor vessels, which marked 1914, has continued during 1915. The experience gained has made it possible for the firm to take up the building of still larger motor vessels than those so far delivered. During the last year five motor vessels have been delivered, one to the Nordstjernan Company, Stockholm, and four to the East Asiatic Company, Copenhagen; a cargo steamer has been delivered to the United Steamship Company. The profits are rather more than 4,000,000 kr. (223,000*l.*). The shareholders obtain 10 per cent., which absorbs 1,000,000 kr.; 1,450,000 kr. are added to the reserve and renewal fund, which now exceeds 4,000,000 kr.; 450,000 kr. are added to the "fund at disposal," which now amounts to 1,000,000 kr.; 419,000 kr. are paid in tantieme; 457,000 Kr. are reserved for war taxes, &c.

A NEW HIGH-SPEED TOOL-STEEL.

Messrs. Darwin and Milner, Limited, of Sheffield, have been experimenting for some months on high-speed tool-steels, their principal object being to find a tool-steel which will be equal to any high-speed tool-steels at present on the market, but which can be produced easily and without the use of alloys subjected to a limited supply, such as tungsten and molybdenum. The firm have now produced an alloy which contains neither tungsten, molybdenum, nor cobalt, which they claim gives excellent high-speed tool-cutting quality. They gave a demonstration at their works last week, and we were permitted to see the new tool-steel cast, the tools ground up and then actually put to work, machining in the firm's experimental lathe a high tensile steel. The casting of the bars was witnessed, and the steel, which is melted in an ordinary crucible furnace capable of yielding high temperatures, is run into either metal or sand moulds and cast to the form desired. When cool, and without any forging or heat treatment, the tools produced are ground on an emery-wheel (dry) and finished on a wet gritstone. They are then ready for immediate use. From this it will be seen there are no complicated forging and heat-treatment processes to go through, and as the tools obtained possess the correct hardness, a number of skilled operations are eliminated.

The tools which we saw cast were 1¼ in. square, but other sizes were exhibited, and some of them were seen in operation. The firm state that they are prepared to cast bars of any shape which are at present in use up to 4 in. square. The firm have tested the new alloy steel for cutting properties on high tensile steels, commercial steels, cast iron, and phosphor-bronze, and claim that it is equal in cutting properties to any high-speed tool-steel on the market, but they have not yet carried out any exhaustive endurance trials, nor have they arranged for any independent trials, and therefore the behaviour of the steel in bulk supply is to some extent unknown. The following trials run on some tools made by the firm will indicate the results which may be expected. The test-piece on which the tools were operating was a chrome-nickel forging of the following composition:—Carbon, 0.32 per cent.; silicon, 0.07 per cent.; manganese, 0.59 per cent.; chromium, 1.26 per cent.; and nickel, 3.28 per cent.

The following endurance tests were made:—(*a*) 1¼-in. new alloy high-speed tool when used as a turning tool on the above forging at a surface speed of 120 ft. per minute; depth of cut, $\frac{3}{32}$ in.; and feed, $\frac{1}{32}$ in.; ran for 7 minutes before it broke down. A tool made from a well-known brand of high-speed tool-steel lasted, under the same conditions, for about 2½ minutes. (*b*) A ¼-in. square new alloy high-speed tool was run for some time with a feed of $\frac{3}{32}$ in. and a surface speed of 55 ft. per minute; the speed was increased to 112 ft. per minute, and later on to 120 ft. per minute. The tool stood this test satisfactorily, and was good for further service. (*c*) The new alloy tool used in test (*a*) was ground up on the Gisholt grinder (dry), finished off on a wet gritstone, and then without any heat or other treatment used in the lathe on turning the test forging with good results. The firm stated that they would be putting the new alloy steel on the market in a few weeks, and that they quite expected that the price would compare favourably with that of any high-speed tool-steel.

RUSSIAN PARLIAMENTARIANS AND BRITISH MUNITION WORKS.

The following translation of a speech delivered by Dr. Shingarev, member of the Russian Duma and President of the National Defence Committee, at a luncheon at Messrs. Vickers', Sheffield, is issued from the Press Bureau: "We are concluding to-day our visit to the works which are manufacturing war material. We saw the powerful navy of Great Britain, her gallant land troops; we saw a few shipyards where with wonderful rapidity new naval forces are growing up, and we visited numerous places where guns, shells, rifles and powder are made. We have been profoundly impressed by the tens of thousands of your workpeople—male and female—who are working incessantly at the consolidating of the military might of your country. Delighted with everything we saw, reassured by the rapid and uninterrupted expansion of the military industry of England and Scotland, we, on concluding our inspection, send our most lively gratitude to all the workers, the entire administration of the works, and the employees, for all they have so courteously shown us, for all they are doing there for the common cause of the Allies' victory. We saw works employed at full speed in turning out thousands of shells in a day, works which have arisen in places where only a few months ago there were no traces of any buildings. We saw new works arising with fabulous rapidity on waste lands and in fields. We know we are firmly convinced of the inevitability of the defeat of our common enemy—Germany. Germany has already attained the highest point of her military strength after having prepared for a war during decades and she has not won yet. England, who, just as Russia, was not prepared for the war, has made during the war enormous efforts. We are still increasing our military forces, their growth is proceeding uninterruptedly and our endeavours will be crowned with victory. . . . We also know that a durable peace can only ensue after a decisive victory, and we are sure that now when the old misunderstandings between England and Russia have been forgotten for ever, when a new alliance has been sealed on the battle fields in a common fight, the peaceful and friendly co-operation of England and Russia will become still stronger and more intimate after the war. A cultural approximation between England and Russia is not only indispensable and useful to both, but it is also very possible and easily attainable."

Prince A. Lobanoff Rostovsky, Member of the Council of Empire, said:—"My colleagues of the Empire and of the Council of the Empire ask me on their behalf to express to you their admiration for the enormous progress made by your works in the cause of the national defence. We have had the great satisfaction to see that your production in matters of war material has doubled itself in certain branches, and in others increased even more, and both in a very short time. Your old-established works have become most important, and, as if by enchantment, new ones have sprung up in a few months, to meet the great requirements of the war. And, again, you have not yet said the last word, for the future of your industrial flight opens to you the widest horizon. Our enchanted eyes have seen during a few days an interminable and continuous series of gun-shops, &c., scarcely a year old. These are marvellous successes—our common cause owes them to a prompt and intelligent mobilisation of English capital, and also, which is more essential, the patriotic *elan* of your brave workers of both sexes. We beg you to believe, and to inform your men and women workers, that their Russian comrades are animated with the same patriotic sentiments, and are equally determined to spare nothing in their efforts to sustain the struggle of our Allied armies, and to co-operate in this way to a final victory over the enemy. We beg your workers of both sexes to receive the brotherly salutation of the Russian men and women workers. We are pleased to learn that among your workmen a Russian worker is to be found who for several years has benefited by your kind treatment."

Berlin to Constantinople.—The Bureau of Railway News and Statistics report that the Constantinople line was open for through traffic on January 15, 1916, there being two trains each way per week, the distance of 1521 miles being covered in 60 hours. From Vienna to Constantinople occupies 48 hours, sleeping berths being charged at 16 marks per night.

The World's Coal.—The production of coal in the principal countries of the world in 1913, the last year preceding the outbreak of the great war, was as follows:—United States, 508,893,000 tons; Great Britain, 287,430,000 tons; Germany, 191,511,000 tons; France, 40,129,000 tons; Russia, 33,335,000 tons; Belgium, 22,858,000 tons; Austria and Hungary, 16,337,000 tons; Spain, 3,783,000 tons; Italy, 701,000 tons; and Sweden, 364,000 tons. The three great coal countries—the United States, Great Britain, and Germany—have naturally in these days of steam a virtual monopoly of the power of the world. One striking feature of our enumeration is the very long lead which the United States have now taken in the matter of coal production. Germany is a rather indifferent third. The coal poverty of Italy is a great drawback to her, as she has to purchase practically the whole of the coal which she requires for the development of her national life. The coal outputs of France and Russia are increasing, but they are still small.

Sir James A. Ewing Appointed Principal of Edinburgh University.—The Curators of Patronage of the University of Edinburgh at their meeting on Monday, under the chairmanship of Lord Provost Sir Robert K. Inches, appointed Sir James Alfred Ewing, K.C.B., Director of Naval Education since 1903, to be Principal of the University, in succession to the late Sir William Turner, K.C.B. The new principal, who is expected to take up his residence in Edinburgh in October, is a Scotsman. He was born in Dundee in March, 1855, the third son of the late Rev. James Ewing. After passing through the High School of his native town, he attended Edinburgh University and took his degree in Arts. At the age of 23 he was appointed Professor of Mechanical Engineering in the Imperial University of Tokio, Japan, and remained there for five years, when he was called to the Chair of Engineering in University College, Dundee. From Dundee he migrated to Cambridge, in 1890, to occupy the Chair of Mechanism and Applied Mechanics in the University until 1903, when the position of Director of Naval Education was given to him. In 1904 he was Rede Lecturer at Cambridge, while he was a member of the Explosives Committee from 1903 to 1906, and from then till 1908 a member of the Ordnance Research Board His research work in magnetism was recognised in 1895, when he was awarded the Royal Medal; while his other honours include C.B., bestowed in 1907, and K.C.B. four years later; LL.D. of Edinburgh and St. Andrews, Hon. D.Sc. of Durham, and Hon. Fellow of King's College, Cambridge.

THE ROYAL METEOROLOGICAL SOCIETY.

The usual monthly meeting of this society was held on Wednesday, the 17th inst., at 70, Victoria-street, Westminster, Major H. G. Lyons, D.Sc., F.R.S., President, in the chair. Mr. L. C. W. Bonacina read a paper entitled "*On the Readjustment of Pressure Differences: Two Species of Atmospheric Circulation and their Connection.*" He attempted to demonstrate a dynamical connection between two essentially distinct types of atmospheric circulation, familiarly exemplified in cyclonic gales on the one hand, and in thunderstorms on the other.

Each type of action has its birth in an initial disturbance in the pressure distribution, or, in other words, in a slight variation of density. If this initial area of disturbance can command the necessary air-currents, the result is the development of horizontal gradient-winds around a cyclonic minimum of pressure, the original difference of pressure becoming greatly exaggerated by the action of the wind itself; but if the initial area of disturbance cannot thus divert surrounding air-currents towards it on account of the exigencies of the existing circulation, the air in it becomes unsuitable or "strained," and is in a position to be suddenly forced upwards by the surrounding slightly denser air in a succession of vertical commotions disposed along one or more axes. Such vertical commotion represents the species of circulation familiar to us in thunderstorms and line-squalls, and in this manner it may be said that the conditions which give rise to thunderstorm action are limited by those which occasion cyclonic circulation. The principles enunciated further explain why it is that in England cyclonic storms, characterised as they are by a wide and diffuse distribution of wind energy, are most frequent and violent around the winter solstice November to February, and that thunderstorms, marked by local patches of concentrated electrical energy, occur mainly round the summer solstice May to August.

Hazards in Handling Gasoline.—According to a tabulation by the Fire Prevention Bureau of New York, 1040 persons were burned to death in the United States during the year 1913 and 3120 persons injured on account of gasoline fires. That would make gasoline responsible for 20 cases of death and 60 cases of injury per week. The damage due to transportation of gasoline on railroads alone increased from 31,000 dollars in 1912 to 118,000 dollars in 1913. The former figures may not be quite reliable; but the dangers were sufficiently serious to make the Bureau of Standards issue a Technical Paper (No. 127) on "Hazards in Handling Gasoline"; the paper is drawn up by Mr. G. A. Burrell. The chief danger, of course, arises from want of caution. Everybody knows that a spark from a leather belt may ignite gasoline, and that a motor-car which is smeared with gasoline by means of a brush for removing grease may be enveloped in fire by any spark or open light. But sparks are rare, and the danger is disregarded. At 63.5 deg F. air may contain from 5 to 28 per cent. of gasoline vapours of different grades. Gasoline-air mixtures are heavier than air and are strictly explosive only within the limits 1.4 and 6 per cent. of gasoline. But both poorer and richer gasoline mixtures will give dangerous flashes capable of travelling back a long way, and a man using gasoline for cleaning will soon be surrounded by an explosive atmosphere.

German Steel Prices.—At the meeting of the members of the German Steel Union, held on May 4, it was decided to raise the prices for half-finished products 20 marks per ton, and for section steel also 20 marks per ton. This last rise makes the price for section steel 160 marks, delivered Diedenhofen, or equal. The new quotations for half-finished products are: ingots, 127½ marks; billets, 132½ marks; bundles, 142½ marks; and plates, 147½ marks per ton. The above rise in the quotations for the products of the Steel Union, excepting railway material, for which the Union does not fix any general prices on account of the long-period contracts with the principal buyers, is the most important which has taken place since the war commenced. No similar rise of 20 marks per ton has even been known to take place in times of peace. The following table shows the rises in the quotations of the Steel Union, decided upon during the war, as far as half-finished products and section steel are concerned:—

		Ingots.	Billets.	Bundles.	Plates.	Section Steel.
		Marks per Ton.	Marks per Ton.	Marks per Ton.	Marks per Ton.	Marks per Ton.
At beginning of war		82.50	87.50	95.00	97.50	110
Third quarter,	1914	90.00	95.00	102.50	105.00	110
Second ,,	1915	97.50	102.50	110.00	112.50	120
Third ,,	1915	102.50	107.50	115.00	117.50	130
Second ,,	1916	107.50	112.50	122.50	127.50	140
Third ,,	1916	127.50	132.50	142.50	147.50	160

The last rise, states the report, is caused by the constant increase of the cost of manufacture, which has made it absolutely necessary to raise the quotations. In railway materials the Prussian State Railways have placed their final orders for 1916 for rails and sleepers, but these fall short of those of 1915. Some extensive sales at favourable prices have taken place to neutral countries, and negotiations are pending about further contracts. As regards section steel, the market continues about the same; there is very little demand for ordinary building purposes, but a comparatively good demand for constructive engineering works and wagon works. The foreign demand was larger in March than in February, and the orders continue to come in, as a further rise in prices is anticipated. The increased prices have given rise to dissatisfaction, for iron works have realised very good profits at the hitherto existing quotations.

SPUR-GEARING.*

By DANIEL ADAMSON, Member, of Hyde.

THE application of toothed wheels to the transmission of power is perhaps the most interesting in the whole range of mechanical science, for the reason that nowhere else is to be found so cordial a co-operation between theory and practice. Papers upon the theory of the proper curves for the teeth of wheels have been presented to the various learned societies connected with engineering almost from the beginning of the work of each of them, while simultaneously the skill of the craftsman has kept pace with the development of the geometry of the subject. What better example of well-directed manual skill can be conceived than the work of the millwrights of, say, one hundred years ago, in dressing the teeth of iron wheels, or fitting new cogs to mortise-wheels? Since that time we have had the invention of the wheel-moulding machine, a monument to the confidence of its originators, followed by gear-cutting machines, using "formers" or "formed" cutters, up to the automatic gear-generating machines of the present day.

Most of the problems of a generation ago have been so well thrashed out by now that to-day a designer need not give so much consideration to the questions of outline or strength, and can devote himself to studying the materials that are likely to be most suitable for his requirements, choosing the proportions that will give the desired durability and providing for careful and accurate construction.

Tooth Shapes and Proportions.—Two forms of tooth have been in general use for many years, the cycloidal curve, Fig. 1 (as described by a point on the circumference of a circle as it rolls along), and the involute curve, Fig. 2 (as made by a point in an imaginary cord unwound from a cylinder). While the involute tooth is formed of one curve, the cycloidal shape, as will be seen from Fig. 1, comprises two curves. This double curve of the cycloidal tooth is difficult to reproduce, and if not accurately executed the gearing will not run well. Further, the exact working centres of the bearings must be strictly adhered to in order to obtain good results, and this is not always possible, whereas the involute shape is easier to originate, and there is a further advantage in that a departure from the correct distance of centres is not fatal to proper running.

The cycloidal shape for the teeth was, however, at first preferred to the involute because of a prejudice against the latter as increasing the pressure on the bearings, but more recently it has been realised that the probable loss from this cause is really very small, for the reason that whereas the thrust between bearings varies as the tangent of the angle of obliquity, the pressure on the bearings increases only as the secant (Fig. 3 and *American Machinist*, 1907, vol. 30, page 805).

The demand for more accurately cut gearing, to give quieter running and greater freedom from shock, has encouraged the development of machinery that will generate the shapes of the teeth on correct geometrical principles, from cutters of simple shape, that can be mechanically produced. This avoids the intermediate processes entailed in making "forming" cutters to outlines drawn by hand in the first instance. The involute form is suitable for such generation, because a rack-shaped cutter, or its equivalent, a rotary hob-cutter, having straight-sided teeth, can be used, the only limitation being that such angles and proportions must be table showing the number of rotary cutters required in a "set" for any given pitch of teeth, according to the limit of accuracy attainable in the shape of the finished cutter. A 12-tooth pinion and a rack to the proportions adopted by Willis (addendum about 0.3 of pitch, dedendum about 0.4) are shown in Fig. 5.

About fifty years ago the Brown and Sharpe Manufacturing Company introduced their standard cutters, which were afterwards adopted generally and very extensively. Their shape is a modified form of involute, the angle of obliquity being 14½ deg., length of tooth above pitch line = 0.3183 of pitch, and below = 0.3683 of pitch. A 12-tooth pinion and rack to Brown and Sharpe's proportions are illustrated in Fig. 6.

In about the year 1886 Mr. Wilfred Lewis advised Messrs. William Sellers and Co., of Philadelphia, to change from the cycloidal system to the involute, and an obliquity of 20 deg. was adopted by that firm (Proceedings, Engineers' Club of Philadelphia, vol. 18, February, 1901). In the annual report of the Engine

Fig. 1. CYCLOIDAL TEETH. 22 TOOTH PINION AND RACK. GENERATING CIRCLE DIAMETER = HALF DIAM.† OF SMALLEST WHEEL IN SET = 12 TEETH.

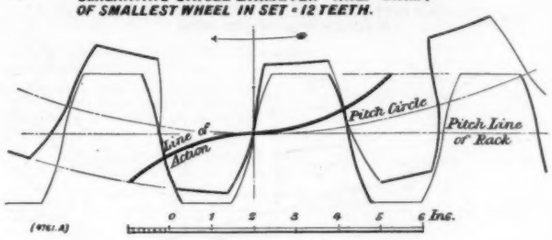


Fig. 2. INVOLUTE TEETH. ANGLE OF OBLIQUITY 14½°. 33 TOOTH WHEEL AND RACK.

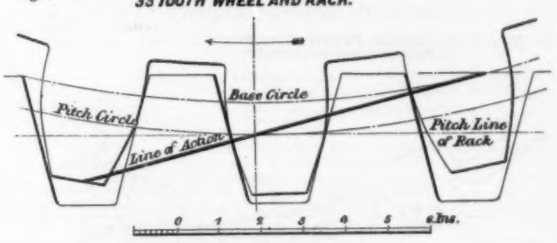


Fig. 3. SHOWING THAT THE BEARING PRESSURE IS NOT SERIOUSLY INCREASED BY AN INCREASE IN THE ANGLE OF OBLIQUITY.

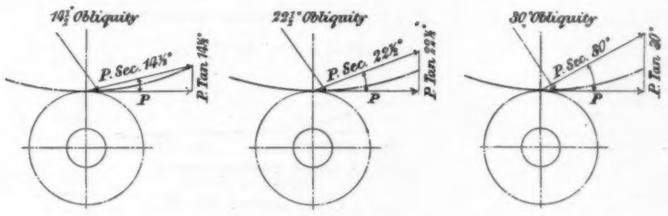


Fig. 5. CYCLOIDAL TEETH (WILLIS) 12 TOOTH PINION AND RACK.

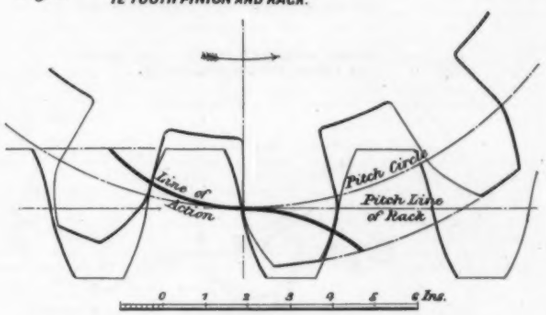


Fig. 4. INVOLUTE TEETH. ANGLE OF OBLIQUITY 14½°. 12 TOOTH PINION AND RACK. (Showing Interference with straight-sided Rack Teeth.)

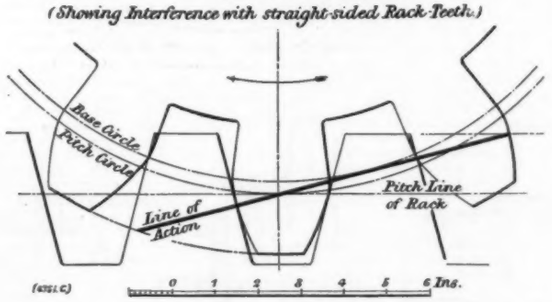
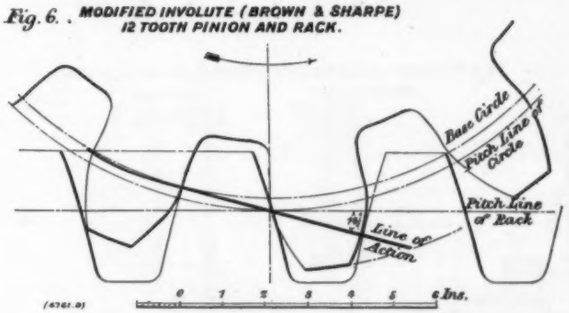


Fig. 6. MODIFIED INVOLUTE (BROWN & SHARPE) 12 TOOTH PINION AND RACK.



chosen as to avoid "interference" or "undercutting" when a pinion of a small number of teeth is to be used.

In the case of a 12-tooth pinion and rack of 14½ deg. obliquity, Fig. 4 (addendum = 0.3183, dedendum = 0.3683), the length of the tooth must be reduced, or the angle of obliquity increased, or a combination of these two variables adopted to avoid "interference." Whatever system is adopted, it is now universally recognised that all wheels and pinions of a set of the same pitch must be interchangeable and work together properly as required, as distinct from the older methods where each pair of wheels was specially made. When establishing such an interchangeable system of gearing, the first factor to be taken into consideration is the minimum number of teeth in the smallest pinion of the set. This has been variously taken as 12, 13, or 14.

Professor Robert Willis (Proceedings, Institution of Civil Engineers, 1838, vol. 2) recommended for cycloidal teeth the use of a constant describing circle of a diameter equal to the radius of the smallest pinion of the set, thus ensuring satisfactory mutual working between all wheels of the same pitch. This is the method generally adopted to-day for cycloidal teeth and gives radial flanks to the teeth of the smallest pinion (*Page's Weekly*, December 29, 1911, page 1201). Professor Willis seems to have been the first to suggest the use of circular arcs to approximate the cycloidal curves (which are difficult to draw in practice), and he developed his odontograph for this purpose. This was later superseded by Grant's odontograph (Gartside's paper, Manchester Association of Engineers, January, 1913). Professor Willis also gave a table showing the number of rotary cutters required in a "set" for any given pitch of teeth, according to the limit of accuracy attainable in the shape of the finished cutter. A 12-tooth pinion and a rack to the proportions adopted by Willis (addendum about 0.3 of pitch, dedendum about 0.4) are shown in Fig. 5.

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In 1893 and 1895 Mr. Archibald Sharp suggested circular arcs for the outlines of wheel teeth, to avoid the difficulty of forming accurate cycloidal or involute curves. He considered that his method would give a smaller departure from correct angular velocity ratio than would arise from the unavoidable errors of workmanship entailed in forming the more correct theoretical curves (Proceedings, Institution of Civil Engineers, vol. 113, 1892-3, and vol. 121, 1894-5). (See Fig. 7.)

In 1899 the present author adopted for the teeth of spur-wheels on cranes an addendum of 0.25 pitch, with a dedendum of 0.32, retaining the Brown and Sharpe angle of obliquity—namely, 14½ deg. Fig. 8 shows a 12-tooth pinion and rack to these proportions; obliquity, 14½ deg. These proportions do not, however, prevent "interference" if a straight-sided rack-tooth is used, as is desirable, for reasons of accurate reproduction. To avoid this objection, the angle of obliquity must be increased to 22½ deg. if a 12-tooth pinion is to be the least of the series; but if 14 teeth can be adopted, then 20 deg. is sufficient.

In addition to facilitating accurate construction, by permitting generation, these modifications have a further advantage in giving a stronger form of tooth, thus allowing a finer pitch to be used for given diameters of wheel and pinion. Reducing the pitch in this manner increases the number of teeth in contact, and thus improves the durability and reduces the noise. The rate of wear is also reduced when more teeth are in gear simultaneously,

* Paper read before the Institution of Mechanical Engineers, Friday, May 19, 1916.

because the contact between the teeth takes place nearer the pitch line, where there is less relative sliding, and for the same reason the loss of power by friction between the teeth is reduced (Robert A. Bruce, *American Machinist*, vol. 24, page 1290, December 7, 1901).

In 1908 Professor R. H. Smith described a method of setting out tooth outlines which was a compromise between the involute and the cycloidal, giving a contact path of "modified hour-glass" shape (Society of Engineers, May, 1908, "The Design and the Waste and Wear of Wheel Teeth"). The height of tooth recommended above pitch circle was equal to one-quarter of the pitch. See Fig. 9.

Lasche's Investigations.—The most valuable publication dealing with the conditions that affect the durability of toothed gearing that has come to the notice of the author is a series of articles by O. Lasche, of Berlin, published in 1899 (*Zeitschrift des Vereines Deutscher Ingenieure*, vol. 43, page 1417). As this has never been translated into English, and is not easily accessible, an extended reference thereto will perhaps be allowed. Lasche says:—

"So long as pitch-line velocities did not exceed 600 ft. per minute, the errors of workmanship and design, that were found even with gear-wheels turned out by first-class firms, did not cause any serious trouble."

To understand more clearly what occurs at the place of contact between the tooth faces, Herr Lasche investigated the variation in the amount of sliding at different parts of the tooth faces and flanks, and from this he developed a "wear characteristic." This "wear characteristic" is dependent upon the contact pressure and the amount of sliding between the contiguous teeth; and, as these quantities vary at each line of contact, it is easily understood why the rate of wear of teeth is found to vary over the different portions of the working surfaces.

When two curved surfaces are pressed together, the breadth of the line of contact is enlarged to an amount depending upon the yielding of the material and upon the rate of curvature of the two surfaces. The usual assumption is, that for a given load and a given material, with contact surfaces of varying curvatures, the displaced volume remains the same for all. The depth of penetration will therefore be less the flatter the curvature and the harder the material. Under the heavy local pressure, due to the contact of two curved surfaces of small radius, the lubricant is first squeezed out. Then the material of the teeth is deformed, and, under severe conditions for frequent repetition of loading, is quickly destroyed.

Figs. 10 and 11 are copied from diagrams in Lasche's original paper, showing respectively the relative sliding between the working surfaces of the teeth and the "wear characteristic" developed therefrom by multiplying the amount of sliding by the estimated corresponding instantaneous load. The relative sliding shown by Fig. 10 may be expressed as the number of units of length of face of the driven tooth passing under one unit of length of face of the driving tooth for a given angular movement of the gears.

These diagrams are only relative, or qualitative, as regards amount of wear to be expected. The exact quantities depend upon too many varying factors, such as elasticity of the material, lubrication, and condition of the working surfaces, to allow for reliable determination. The most noticeable feature of these diagrams is the relatively large amount of sliding that takes place at the point of the teeth, as compared with the regions near the pitch circles where the motion is more purely rolling. Also it may be pointed out that as the teeth

TABLE 1.—*Duration of Contact.*

For Involute Teeth 20 deg. Obliquity. Addendum, one-quarter of Circular Pitch.

No. of Teeth.	12	15	20	30	36	45	60	75	100	150
12	1.17	1.19	1.21	1.25	1.26	1.28	1.29	1.30	1.32	1.33
15	1.19	1.21	1.24	1.27	1.29	1.30	1.32	1.33	1.34	1.35
20	1.21	1.24	1.27	1.30	1.32	1.33	1.35	1.36	1.37	1.38
30	1.25	1.27	1.30	1.33	1.35	1.36	1.38	1.39	1.40	1.41
36	1.26	1.29	1.32	1.35	1.37	1.38	1.40	1.41	1.42	1.43
45	1.28	1.30	1.33	1.36	1.38	1.40	1.41	1.42	1.43	1.44
60	1.29	1.32	1.35	1.38	1.40	1.41	1.43	1.44	1.45	1.46
75	1.30	1.33	1.36	1.39	1.41	1.42	1.44	1.45	1.46	1.47
100	1.32	1.34	1.37	1.40	1.42	1.43	1.45	1.46	1.47	1.48
150	1.33	1.35	1.38	1.41	1.43	1.44	1.46	1.47	1.48	1.49

Fig. 7. CIRCULAR TEETH (SHARP). 12 TOOTH PINION AND RACK.

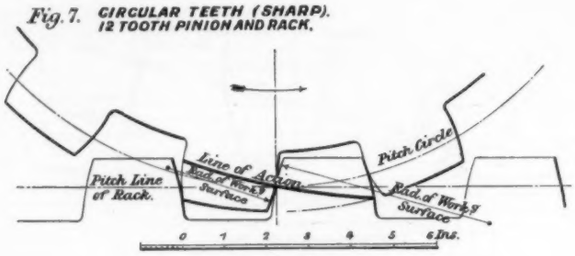


Fig. 8. SHORT TEETH 14½° OBLIQUITY INVOLUTE (MODIFIED). 12 TOOTH PINION AND RACK.

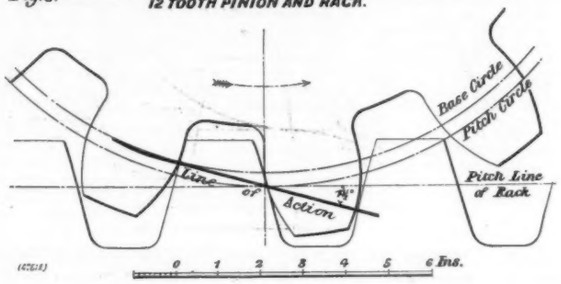


Fig. 9. SANGS MODIFIED TEETH. (R. H. SMITH). 12 TOOTH PINION AND RACK.

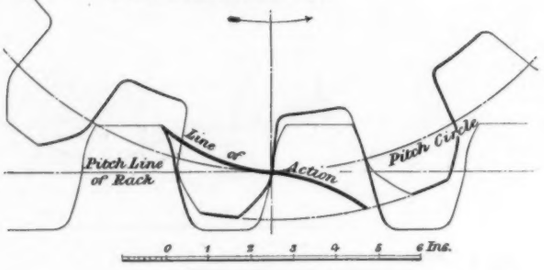


Fig. 10. SPECIFIC SLIDING (INVOLUTE TEETH). (From Lasche's Fig. 8.)

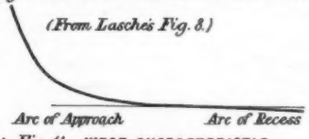


Fig. 11. WEAR CHARACTERISTIC (INVOLUTE TEETH). (From Lasche's Fig. 10).

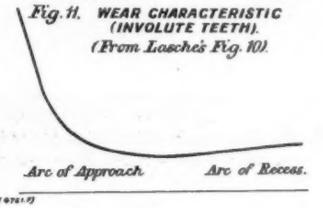
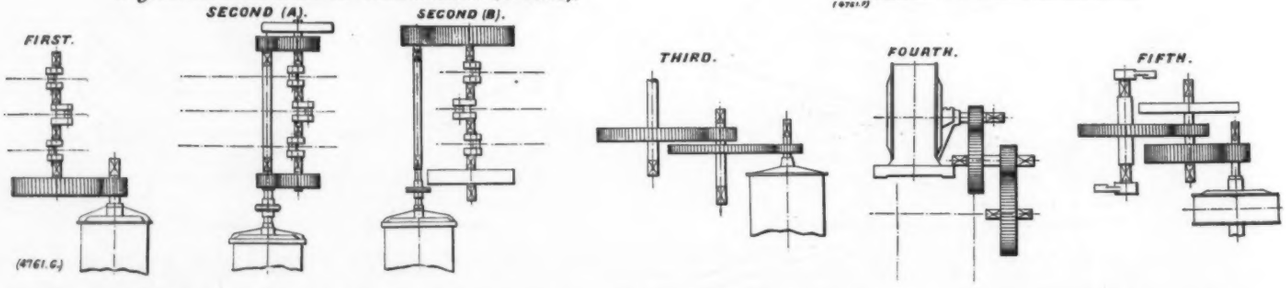


Fig. 12. FIVE EXAMPLES OF TRANSMISSION (LASCHE).



approach the pitch point (during the arc of approach) they slide into one another, which is a less favourable condition than arises after the teeth have passed the centre line (during the arc of recess).

The next important condition affecting the working of gear-teeth is the relation between the theoretical arc of contact and the circumferential pitch, called for convenience the "duration of contact," and usually expressed in terms of the circumferential pitch. When the duration of contact is unity, each tooth in turn begins its work just as the preceding one comes out of action. If the duration of contact is greater than unity, but less than two, it means that a tooth works alone until the following tooth engages, and the load is then distributed between the two teeth in gear until the first pair of teeth come out of action, leaving the second pair only in gear. Professor R. H. Smith, in the paper read before the Society of Engineers, and already alluded to, suggested a contact path of such a shape as to give a "duration of contact" of about 1¼ pitches. This ensures that each following pair of teeth is well in gear before the preceding pair has parted contact. Figs. 10 and 11 show that when the theoretical arc of contact exceeds unity, the duty will be distributed between the different teeth in contact at a time when the rate of wear would otherwise be at its highest value.

Table I., annexed, shows the theoretical number of teeth in contact depending upon the number of teeth in the wheel and pinion. Assuming two teeth continuously in contact, a third pair will come into action just as the first pair are leaving, and at the same time the second pair will be in contact at the pitch point. The exact division of the load, between two pairs of teeth in action under these circumstances, is uncertain, as it depends upon many factors, such as elasticity, accuracy of workmanship, &c., and recent authorities suggest that while a large arc of contact is desirable to reduce wear and tear, yet it must still be assumed that only one pair of teeth are in contact when calculating the strength of the gearing (see discussion on Marx's paper, Amer. Soc. Mech. Eng., 1912, vol. 34, page 1376). It is evident that the minute surfaces involved at the commencement of contact cannot carry as much as the more ample surfaces nearer the pitch line, hence the wear will quickly remove material from the points and roots of the teeth, and leave the bulk of the load to be transmitted by the teeth in contact near the pitch point.

[Büchner says that on this account involute teeth tend to approximate to cycloidal shapes when in use (*Zeitschrift des Vereines Deutscher Ingenieure*, vol. 46, page 279, February 22, 1902)].

When wear takes place near the pitch circle, the resulting error of movement of the teeth points is magnified, and the points gouge out portions of the roots of the teeth of

the other wheel. This accentuates the wear and gives rise to certain high stresses in a radial direction, which are not usually provided for in the design of the rims. Although new wheels may run quietly at first, yet as soon as undue wear occurs the correct shape of the teeth is departed from, and the first requirement of toothed gearing—namely, transmission at a uniform angular velocity—is no longer fulfilled. The resulting rapid fluctuations in angular velocity give rise to chattering and hammering, which tend to destroy the structure of the material much more rapidly than the usual sliding and rolling of the surfaces.

A study of the "wear characteristic" diagram, Fig. 11, page 512, will show the desirability of reducing the addendum, and by this means retaining in use only those portions of the tooth surface that endure approximately an equal amount of wear, thus retaining the correct original shape as long as possible. A reduction in the height of tooth and an increase in the angle of obliquity each improve the strength of the tooth, and the only important limitation in this direction is the reduction in duration of contact that follows from these modifications. The improved "wear characteristic" that would follow is an answer to the criticism that the increased angle of obliquity necessarily increases the amount of backlash.

The factors to be considered when estimating suitable proportions to resist wear are :—

P = pressure to be transmitted at pitch line,
N = number of revolutions per minute,
e = estimated number of teeth in contact,
b = breadth of teeth,

and a table of actual examples from practice and experiment is given in Lasche's original paper to enable a suitable value to be placed upon $\frac{P N}{e b}$ according to the condition of the working.

The first of these examples, Fig. 12, refers to a 50-horse-power transmission at 575 revolutions per minute with a raw-hide pinion of 26 teeth, 1¾ in. pitch by 6 in. wide, gearing into an iron wheel having about 220 cast teeth. The pressure per inch of width of tooth (130 lbs.) was found to be too great for rough cast teeth, and the gearing was increased in width to bring the load down to 93 lb. per inch of width; the teeth of the new wheel were machine cut, and the result was very satisfactory. The pitch-line velocity was 2150 ft. per minute.

In the second example, two raw-hide pinions of 18 teeth, 1¾ in. pitch by 6 in. wide, were arranged "in parallel" to transmit 50 horse-power between them at 575 revolutions per minute. The pressure per inch of tooth width, assuming one pinion carrying the load alone (215 lb.), was too great, the "parallel" arrangement was unsatisfactory because the pinions were not able to divide the load equally, and in addition the damp situation hastened the destruction of the raw hide. The "parallel" arrangement was altered to a single pair of wheels and the width increased to 15¾ in., giving a load of 80 lb. per in. of width with satisfactory results. The pitch-line velocity was 1300 ft. per minute. Fig. 12A shows the original arrangement, and Fig. 12B that adopted afterwards.

The third example was designed to transmit 75 horse-power at 575 revolutions per minute, the wheel, about 136 teeth, and pinion, 35 teeth, 1¾ in. pitch, 5¾ in. wide, each being of steel with machine-cut teeth. The pinion teeth broke frequently because the first-motion pinion was rigidly connected to the large mass of the revolving armature, and the first-motion wheel was similarly very close to the second-motion pinion. The pitch-line velocity was about 2460 ft. per minute. The load transmitted works out at about 180 lb. per inch of width, which would give a working stress of only about 1300 lb. per sq. in. in the teeth. Errors in workmanship amounting to 0.5 mm. (say 0.02 in.) in pitch, however, that might have been unnoticed at lower velocities, or with more flexible attachment, gave rise to the trouble mentioned, and the drive had to be entirely rebuilt.

The fourth example exhibited the same faults as the one last described. The motor was of 96 horse-power at 690 revolutions per minute, driving a bore-hole pump. Pinion 23 teeth, 1.35 in. pitch, 7 in. wide, wheel about 70 teeth. The pinion was of phosphor-bronze in this case, with a load of 250 lb. per inch of width. The velocity (1800 ft. per minute) is too high for metallic wheels, unless the greatest accuracy in construction and care in installation are available.

The fifth example was a transmission of 100 horse-power with a raw-hide pinion, 26 teeth, 1.85 in. pitch, 11 in. wide, at 480 revolutions per minute, the load per inch of width being 153 lb., and the velocity 1900 ft. per minute. Although the transmitted load was not excessive, yet breakages of the teeth occurred through the same faults as in the third and fourth examples, and suggestions were made to substitute rope-driving for the first reduction, or a slow-speed motor. Each of the five examples quoted is shown diagrammatically in Fig. 12.

Four examples are given, where the experience has been quite satisfactory, of raw-hide pinions gearing with cast-iron wheels, the powers ranging from 5 to 75 horse-power, the loads per inch of width from 34 to 136 lb., and the pitch-line velocities about 1800 ft. per minute. (See Table annexed for particulars.) The average for $\frac{P N}{e b}$ for these is about 32,000 in English units (pounds per inch).

[The average of fifty examples of raw-hide pinions "in service and giving satisfaction," given by Livingstone (*Electrician*, March 19, 1909, page 892), gives $\frac{P N}{b}$ as 112,000, and $\frac{P}{b}$ = 115 lb. per inch of face.]

Three examples given by Lasche of delta-metal pinions working satisfactorily with steel wheels on crane motors

Four Examples of Raw-Hide Pinions with Cast-Iron Wheels.

H.P.	R.P.M.	Pitch.	Breadth.	Teeth in Pinion.	Teeth in Wheel.	Velocity.	Load on Teeth in lb.	$\frac{P N}{e b}$
		in.	in.			ft. per sec.		
5	1440	0.49	2.95	28	112	27.56	99	25,400
15	960	0.99	4.72	25	100	32.8	246	25,900
40	720	1.236	7.87	25	100	30.84	705	35,000
75	575	1.496	10.24	25	100	29.53	1380	43,000

varying from 15 to 75 horse-power have loads per inch of width varying from 175 to 350 lb., the pitch-line velocity being from 1000 to 1200 ft. per minute; average for $\frac{P N}{e b}$ is about 100,000 (see Table below).

[As confirmation of the above, the author may be allowed to say that he adopted, more than twelve years

Three Examples of Delta Metal with Steel Wheels on Cranes.

H.P.	R.P.M.	Pitch.	Breadth.	Teeth in Pinion.	Teeth in Wheel.	Velocity	Load on Teeth in lb.	$\frac{P N}{e b}$
		in.	in.			ft. per sec.		
15	960	0.618	2.36	24	—	19.68	415	93,600
40	720	0.618	4.72	24	—	17.72	1235	104,500
75	575	0.866	7.08	24	—	16.40	2470	111,300

ago, a maximum of 130,000 for $\frac{P N}{e b}$ for intermittent crane work for steel pinions gearing with steel wheels, and 53,300 for raw-hide pinions under similar conditions, assuming a duration of contact equal to 1½ pitch, and the results have been quite satisfactory.]

Referring to the variation in stresses due to irregularities in pitch, Lasche gives calculations of a typical example from practice showing that while at moderate speeds this is not serious, yet as the excess load due to irregularities will increase as the square of the velocity, it is evident why trouble is experienced, at higher peripheral speeds, that cannot be accounted for by calculations based upon the transmitted load alone. Hence the greater care that is essential for success at the high speeds now in use. (An abstract of Lasche's calculations on this point is given in Appendix II., page 34.)

Professor R. H. Smith also refers to the increased stress caused by irregularities in the pitch or shape of wheel teeth (Society of Engineers, 1908).

Another important detail elaborated by Lasche is the advisability of separating revolving masses, as, for example, armatures of motors, from adjoining masses, such as the large gear-wheels of the second motion, by some elastic medium, such as a length of shaft or a flexible coupling, so as to allow slight variations in angular velocity, due to unavoidable errors in gear-cutting, to take place without giving rise to destructive loads between the teeth. Satisfactory running had been obtained at the date of Lasche's paper (1899) (by careful workmanship, installation and lubrication) with milled cast-iron wheels and raw-hide pinions, at 960 revolutions per minute, 2400 ft. per minute, and 112 lb. per in. of face, and with cast-steel wheels and delta-metal pinions at 720 revolutions per minute and 1800 ft. per minute. Wear was hardly noticeable on the delta-metal and cast-steel combination after milions of revolutions at pressures up to 700 lb. per inch of width. For lubrication of raw hide, a mixture of talc graphite and resin proved satisfactory.

[From these references to Lasche's investigations, it is very evident that durability depends upon accuracy of construction as much as upon correctness of design and suitability of the material used.]

Materials.—It is upon the question of the most suitable materials that the author hopes to learn most, and with a view to eliciting some discussion, he proposes to review briefly the requirements of the conditions involved. For many years cast iron was universally adopted for spur-gearing, and then gun-metal was used to some extent, but the elastic limit of these materials is too low for use under modern conditions as to speed and load (Christie, Proceedings, Engineers' Club of Philadelphia, vol. 18, page 43, February, 1901).

Cast steel has been largely used in recent years in place of cast iron, with satisfactory results, but the demand for greater reliability and economy in space has called for forged steel of varying qualities. The milder qualities of steel first adopted, say up to 0.3 per cent. carbon, gave trouble by abrasion (Christie, *loc. cit.*), and also by change of tooth form under the percussive action they experience when in use under heavy loads, and case-hardening the teeth has been adopted to some extent to overcome this weakness.

It is now generally agreed that for important gearing, where space is limited, the elastic limit of the steel must be raised from, say, 20 tons to 40 tons per sq. in. (Litchfield, Trans. Amer. Soc. Mech. Eng., 1908, page 972), and the only difference of opinion is as to whether this should be done by merely increasing the carbon contents to, say, 0.6 per cent. or more, or by using other alloys, such as nickel, manganese, chromium, vanadium, &c., with or without suitable heat-treatment to toughen and harden the steel. One objection raised to high-carbon steel is the risk of brittleness ensuing from careless treatment (Logue, *American Machinist*, vol. 31, 1908, Part 1, page 95). Revillon recommends nickel steel, because all requirements can be met without a complicated heat treatment (Iron and Steel Institute, Carnegie Memoirs, vol. 1, page 218).

It should not be overlooked that while heat treatment may be quite feasible with large masses of steel, such as armour-plates and gun-tubes, where the value of each piece makes it possible to maintain an expensive laboratory and staff to check the processes and the results, this is not so convenient in ordinary machine-shops. Whatever material is adopted, it is advisable to make the pinion of harder material than the wheel (Logue, *American Machinist*, vol. 31, Part 2, 1908, page 115) in order to divide the wear equally between the two, and thus prolong their useful life by enabling the teeth of both wheel and pinion to retain their original accuracy and shape as long as possible. If undue wear affects the pinion, this in turn reacts upon the teeth of the wheel and both suffer. More attention will have to be given to the constituents of steel used by engineers as requirements become more onerous. Some engineers connected with large steel works are already including in their specifications of machinery to be purchased a stipulation that phosphorus and sulphur in steel forgings and castings must not exceed 0.04 per cent.

(To be continued.)

SURFACE-TENSION EFFECTS IN METALS.

*Surface-Tension Effects in the Inter-Crystalline Cement in Metals and the Elastic Limit.**

By F. C. THOMPSON, M.Met., B.Sc. (Demonstrator in Metallography in the University of Sheffield).

(*Continued from Page* 474.)

Dynamic Stresses.—We may now turn our attention to a consideration of the effects of alternating stresses, on the basis of the surface-tension theory.

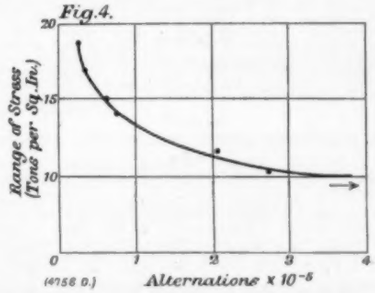
When a tensional stress is applied to a normal metal, the withdrawal of adjacent crystals will be very small if the stress applied is small compared with the mutual attraction between the grains. When, however, the two stresses become comparable, a more marked separation should occur. This increase of d of equation (2) will result in a lowering of the resistance to further stress, which is measured by E. Thus we may consider E as a measure of the resistance to alternation of stress, while d is a corresponding measure of the applied force when this exceeds some minimum value. Below this value the resistance would be infinite. Above it, however, the relationship of the resistance to the maximum value of the stress applied is expressed by the relationship

$$Ed = \text{const.}$$

This is the equation of a rectangular hyperbola.

The resistance, therefore, of a metal to alternating stress should be infinite for small stresses. Beyond a certain limit, however, it should commence to decrease, ultimately becoming zero when the stress applied is great. The results of many experimenters in this field of work are of exactly this type. Some results of Wöhler on repeated tensions, recorded by Unwin, "Testing of Materials of Construction," page 373, are plotted in Fig. 4.

Fig. 4.



The theory of surface tension is of great interest also in connection with the influence of the rapidity with which the stress is applied. The sudden stretching of a soap film is accompanied by a very distinct cooling. If, however, the stretching be done slowly, the temperature is maintained constant by the inflow of heat from the surroundings. Now since the surface tension of a liquid increases as the temperature is lowered, it will be at once seen that if the theory be true which connects the elastic limit of a metal with the surface tensions between the crystalline grains, the rate at which a stress is applied should produce a distinct difference of mechanical properties. The influence, however, will be less in metals than in many other materials, on account of the high thermal conductivity of the former, while it should be greater in large masses than in fine wires, since in the latter case the inflow of heat can occur much more quickly than in the former. It is also to be expected that only in cases of very rapid loading will any appreciable effect be observed, since at all more moderate rates the conduction will be sufficiently great to maintain isothermal conditions.

It is also possible to predict the remarkable cases of fracture first observed by Wöhler under stresses lower than the normal elastic limit. It has been shown by Ewing and Humfrey (19†) that under such stresses the friction of crystal against crystal, and especially on the plane of slip, causes the amorphous material to be produced in quantities which can be recognised microscopically. Such an increase of thickness d would be

* Paper read before the Iron and Steel Institute, May 5.

† These figures refer to a Bibliography at the end of the paper.

relatively very great, and the reduction of the interfacial attractions which would result affords a very ready explanation of the ultimate fracture under stresses less than the assumed original elastic limit.

Another aspect of the theory in connection with rapidly applied stresses is important.* The sudden stretching of a film, such as those between the crystals in a metal, involving work done against surface tension, will result in a cooling effect :—

$$= 2\,\theta\,A\,\beta,$$

where :—

θ is the absolute temperature,
A the increase of area of the film,
and β the temperature coefficient of the surface tension T.

Now, if a test-piece be subjected to a stress dp, applied instantaneously, so that the thermal changes are not removed by conduction, the elongation de is the algebraical sum of that due to the increased pull and of that due to the change of temperature. Thus if q is Young's modulus for steady strain (the isothermal modulus), w the coefficient of linear expansion, and $d\theta$ the change of temperature, then :—

$$de = \frac{dp}{q} + w\,d\,\theta.$$

Neglecting the change of temperature due to the stretching of the films :—

$$d\theta = -\frac{w\,T_o\,d\,p}{J\,K\,\rho}$$

where :—

T^o is the temperature,
K ,, specific heat,
J ,, mechanical equivalent of heat,
and ρ ,, density.

$$\therefore \frac{d\,e}{d\,p} = \frac{1}{q} - \frac{w^2\,T_o}{J\,K\,\rho} = \frac{1}{q'}$$

where q' is the adiabatic modulus. Knowing ρ, K, w, and ρ, q' can be deduced, with the result that q' should never be so much as 1 per cent. greater than q.

It is possible, however, to determine q' directly by acoustical methods, and Wertheim's results indicated that the adiabatic modulus was in some cases 20 per cent. greater than the isothermal. Now taking into account the cooling of the films due to the sudden stretching :—

$$-d\,\theta = \left(\frac{w\,T_o\,d\,p}{J\,K\,\rho} + 2\,\theta\,A\,\beta\right).$$

If the crystals are considered as cubes, n per centimetre, and if σ is Poisson's ratio for the metal—*i.e.*, the ratio of the lateral contract $10n$, produced by the stress to the longitudinal extension—the change of area of the films round each crystal due to a stress $a\,\rho$ may be shown to be :—

$\frac{4\,d\,e'}{n}(1 - 2\,\sigma)$, where $d\,e'$ is extension of each crystal.

$\therefore$ the change of area per cubic centimetre, since each film abuts two crystals :—

$$= \tfrac{1}{2} \cdot \frac{4\,d\,e'}{n}(1 - 2\,\sigma)\,n^3.$$

But

$$n\,d\,e' = de$$

$\therefore$ change of area per cub. cm. (A)

$$= 2\,d\,e\,(1 - 2\,\sigma)\,n.$$

But

$$de = \frac{d\,p}{q}$$

$$\therefore \quad A = \frac{2\,d\,p}{q}(1 - 2\,\sigma)\,n,$$

whence :—

$$-d\,\theta = \left\{\frac{w\,T\,d\,p}{J\,K\,\rho} + 2\,\theta\,\beta\,\frac{2\,d\,p}{q}(1 - 2\,\sigma)\,n\right\}$$

$$\therefore \quad \frac{d\,e}{d\,p} = \frac{1}{q'} = \frac{1}{q}\{1 - 4\,\theta\,\beta\,w\,(1 - 2\,\sigma)\,n\} - \frac{w^2\,T}{J\,K\,\rho}$$

$\frac{1}{q'}$ is thus smaller than it would be if the surface-tension effect were neglected, or q' is greater. The adiabatic Young's modulus is therefore greater than the value obtained by omitting temperature changes due to the surface-tension phenomena between the crystalline grains. An explanation is therefore offered by this fact of the divergence hitherto of the calculated and observed values.

The values of all the constants for iron are known, with the exception of the temperature coefficient of the surface tension. Assuming, however, that the critical temperature is 10,000 deg. Cent., then for a metal with 300 crystals per centimetre the ratio of $\frac{q'}{q} = 1.28$; neglecting this effect, however, $\frac{q'}{q}$ is only 1.0026. This appears to the author to be almost proof positive of the truth of the theory propounded. Not only is the difference between the adiabatic and isothermal Young's moduli in the proper sense, but the effect is sufficiently great to explain all of the discrepancies hitherto unaccounted for.

Some further details, all pointing in the same direction, may here be noted. Hanriot has recently shown that a cube of metal subjected on every face to considerable hydraulic pressure was apparently hardened, although no distortion of the crystals could be detected microscopically. Cleavage slipping, therefore, presumably did not occur, so that the hardening was not due to an increase in the quantity of the amorphous modification. The result admits of a simple explanation in view of the theory under consideration. Pressure from all sides would tend to produce closer contact between adjacent crystals, so that d in equation (2) would be decreased, and E in proportion increased.

The second point arises from the discovery of Schottky, that the strength of gold-leaf begins to decrease when the thickness is reduced below a certain value. The greater reduction would produce, if possible, more amorphous material than before, and so should, according to present conceptions, give a still harder material. Such a result, however, would follow necessarily from the surface-tension theory of strength. The increase of strength of a material stressed beyond the yield-point has already been dealt with, the increased resistance being referred to the increased area resulting from cleavage slipping across which surface-tension attractions can act. When the metal has been subjected to a very great deformation, as in the beating of gold into leaf, the amount of the amorphous modification produced will be correspondingly large and the intercrystalline films thick. Since d in equation (2) is lowered, the strength must then fall at the same time.

The behaviour of a test-piece of normal ductile metal, stressed in tension, after its maximum stress has been reached, is characteristic and familiar. The waist that is formed at a certain point of the specimen is an indication of a condition of marked instability and of a continuous lessening of the resistance to the pull applied. Such instability is closely similar to that found in cylindrical soap films, in which the length of the film exceeds the semi-circumference. If the interiors of two such long films are connected, a film which is already bulging out grows bigger and bigger until it bursts, while one whose sides are curved inwards collapses. Now the usual test-pieces are of a size corresponding to these unstable films—*e.g.*, the common type, 2 in. long and 0.564 in. in diameter; and in these, when the maximum stress is reached, a condition approximating to the mobility of a fluid is reached. Under the influence of surface-tension forces this unstable condition results in lateral contraction commencing at a certain point, which contraction then increases until the test-piece breaks. It is a well-known fact that very short pieces show much less elongation and reduction of area at the point of fracture than do longer ones. In such cases the cylindrical film is always stable. It is possible that to this fact should really be attributed the practically recognised result that the enlarged ends of the test-piece diminish its drawing out. Such test-pieces also give distinctly higher tensile strength than do longer, thinner ones. The following concrete example of these conditions is taken from Unwin's "Testing of Materials of Construction," page 109. A steel bar $2\frac{1}{2}$ in. in diameter had its diameter turned down to $1\frac{1}{2}$ in. for a length of $2\frac{1}{2}$ in. Such a bar is just on the limit of instability, since the semi-circumference is 2.3 in. A second test-piece from the same bar was made by turning a groove with a slightly rounded bottom. This is the shortest possible test-piece, and a similar liquid film would be stable. The normal piece registered a maximum stress of 35.9 tons per sq. in., with an elongation of 60 per cent. on 2 in., and a reduction of area of 54.6 per cent. The grooved piece broke under a stress of 53.25 tons per sq. in., and the elongation and contraction were practically nil.

Electrical and Magnetic Properties.—It has recently been shown by the author (20) that the electrical resistance of a given sample of metal is the sum of that of the crystalline part and that of the crystal boundaries.

If ρ_1 is the specific resistance of the sample,
ρ_2 the specific resistance of the crystalline material,
n the number of crystals per centimetre, and
r the resistance of 1 sq. cm. of boundary perpendicular to the direction of the current ;

then

$$\rho_1 = \rho_2 + n\,r.$$

For the iron already considered :—

$$\rho_1 = 6.83 + 1.72\,n \times 10^{-3} \text{ microhms per cub. cm.}$$

The drastically annealed sample had a specific resistance of 7.15 microhms per cub. cm.; that of the normalised sample was 7.51 microhms, and that of the quenched and tempered, 7.99 microhms.

Now since empirically :—

$$E = k\,n^{\frac{1}{3}}\,T$$

$\frac{\rho_1 - \rho_2}{E^3}$ should be a constant.

If the resistances are expressed in ohms per cubic centimetre and the elastic limit in tons per square inch, the values for this term are :—

For annealed iron	...	...	...	47.5
For normalised iron	...	...	...	39.4
For quenched and tempered iron			...	42.3

values which are approximately constant.

In view of the close relationship of the surface tension to intrinsic pressure, and of this to the hardness of a metal, it is interesting that for the samples of iron already treated of :—

$$e = 300\ B^{1\cdot5}$$

where B is the Brinell hardness, and e is the hysteresis loss per cycle.

(To be continued.)

LEYLAND IRON ORE.—On account of the increasing difficulties of obtaining tonnage and other impediments to transport by sea, work has been knocked off one day a week, Saturday, both at Malmberget, Gellivare, and at Kirunavare. The company has been very reluctant to take this step, but it has been found impossible to find the necessary storage accommodation. The company has lost a considerable amount of its own tonnage of late, which circumstance further enhances the transport difficulties.

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Australia.—With reference to the new underground electric railways in Sydney, the Sydney office of His Majesty's Trade Commissioner for Australia has forwarded a copy of a detailed report of the Chief Engineer to the New South Wales Public Works Department on the proposed railway undertakings. The works recommended in this report are the following :—The electrification of the inner zone suburban railways to Parramatta, Hornsby, Sutherland, and Bankstown; the construction of the City Electric Railway, and electric railways to the eastern, western and nothern suburbs; the construction of two long-span cantilever bridges across the harbour, of 1600-ft. and 1350-ft. centre spans respectively; the electrification of the outer zone suburban railways to Penrith, Campbelltown, Waterfall, the Hawkesbury River, and various other small branches in the suburban area; and the construction of underground tramways. The total approximate cost of these undertakings, which has been approved, is 20,000,000*l.*, exclusive of land resumption. The report also contains recommendations regarding the Sydney Harbour (North Shore) bridge, in connection with which a Bill was recently stated to be in course of preparation.

Siam.—With reference to the call for tenders by the Siamese Royal Railway Department (broad gauge) for the supply of three steel viaducts, His Majesty's Consul-General at Bangkok reports that the contract has been awarded to a Dutch firm, whose name, together with the quoted prices, &c., may be obtained by United Kingdom contractors interested on application to the Commercial Intelligence Branch.

Republic of Colombia.—With reference to the measures to be taken by the Colombian Government to combat the yellow fever at Buenaventura, it is notified that the *Diario Oficial*, Bogotá, publishes a Presidential Resolution, dated February 21, regarding the works to be carried out. It is stated that although the yellow fever has disappeared, it is urgent that every effort should be made to prevent its reappearance, and with that object in view the following measures will be taken. The inspection of private houses to ensure the fulfilment of the sanitary arrangements will be continued. Special attention is to be paid to works necessary for protection against inundations of the sea at high tides. Arrangements will be made for the purchase from abroad of wire netting for protecting doors, windows, cisterns, &c., which will be sold to the public at cost price. Crude petroleum for continuing the treatment of the marsh land as a measure of defence against yellow fever will also be obtained from outside the Republic. Large reinforced-cement tanks will be constructed in the higher part of the town to receive rain water, which will be distributed through pipes; these tanks will be covered with wire netting. Other works to be undertaken include the construction of a hospital station, the improvement of the market place, the installation of disinfecting apparatus, &c.

AMERICAN COAL EXPORTS.—The exports of coal from the United States in January this year were 1,217,130 tons, as compared with 823,444 tons in January, 1915. The total of 1,217,130 tons was made up as follows :—anthracite, 274,986 tons; bituminous, 942,144 tons.

CENTIGRADE FOR FAHRENHEIT SCALE.—According to the *Iron Age*, Dr. Carl Hering presented, at a recent meeting of the American Electrochemical Society, a resolution endorsing a Bill now in Congress to the effect that in all Government publications the Centigrade scale should ultimately be substituted for the Fahrenheit, probably at the end of four or five years. The resolution was adopted unanimously. In the meantime the two scales are to be used side by side.

CANADIAN RAILWAYS.—The length of new line brought into operation in Canada since 1910 has been 10,852 miles. The addition carries the aggregate mileage in operation to 35,184 miles, made up as follows :—Ontario, 10,702 miles; Quebec, 4677 miles; Manitoba, 4,498 miles; Saskatchewan, 5327 miles; Alberta, 3174 miles; British Columbia, 3100 miles; New Brunswick, 1962 miles; Nova Scotia, 1367 miles; Prince Edward Island, 275 miles; and Yukon, 102 miles. In 1910 the capitalisation of Canadian railways was 1,210,297,687 dols.; in 1915 the corresponding aggregate had increased to 1,875,810,888 dols. These totals did not include the assistance which the Canadian Government has given in aid of Canadian railway development. For instance, the Dominion Government has built the eastern section of the Transcontinental line, at a cost of 152,802,706 dols., while the Federal and provincial governments also guaranteed Canadian railway bonds during the last five years to the extent of 409,869,165 dols. Canadian railway revenue declined last year as compared with 1914 to the extent of 43,240,457 dols. This was explained to some extent by a decline in freight traffic last year from 101,393,989 tons to 87,204,838 tons. Canadian railway earnings have, however, been steadily growing during the last twenty years. In 1895 they were $46,785,486; ten years later they stood at $106,467,198; and in 1913 they reached their maximum in any one year, viz., $256,702,703.

* Poynting and Thomson, "Properties of Matter," page 134.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

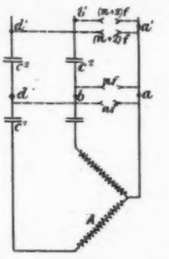
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

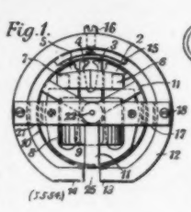
ELECTRICAL APPARATUS.

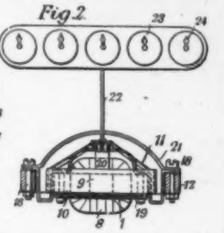
4345/14. La Societe Marius Latour et Compagnie, Paris, France. Wireless Telegraphy. [1 *Fig.*] February 20, 1913.—This invention relates to high-frequency alternating currents for wireless telegraph or telephone systems, and has for its object to provide means for the transformation of currents of $n.f.$ periods into currents of $(n+2)\ f$ periods. n is any whole number, and f refers more particularly to the frequency proper of the machine which is used for the transformation in view. It is known that in the case of an ordinary alternator, the frequency proper corresponds to the number of revolutions per second multiplied by the number of pairs of poles of the alternator. The invention consists in the transformation of polyphase currents at $n.f.$ cycles into polyphase currents at $(n+2)\ f$ cycles by means of a dynamo-electric machine having a polyphase winding on its stationary part and a single-phase winding on its rotating part, said polyphase winding being fed by polyphase currents at $n.f.$ cycles. Assume that two-phase currents, having a frequency $n.f.$ obtained from any source, are introduced through the terminals a, b, d into the winding of the two-phase stator A. B is the single-phase rotor. The capacities C^3 are for the purpose of eliminating the self-induction of the windings at the frequency $n.f.$ These two-phase currents having a frequency of $n.f.$



give rise to a rotating field, the speed of which is $n.f.$ Therefore, if the rotor rotates hypothetically at the speed f in the direction opposite to the rotating field, a current having the frequency $(n+1)\ f$ is induced in its winding. This single-phase current produces an alternating field which may be decomposed into two rotating fields rotating in opposite directions to each other and at the speed $(n+1)\ f$ with respect to the rotor. With respect to the stator, which is stationary, one of the two component fields rotates at the speed $(n+1)\ f - f = n.f.$, and combines its action in the usual manner with the field of the stator having a frequency $n.f.$; while the other of the component fields rotates in space at the speed $(n+1)\ f + f = (n+2)\ f$, and therefore induces in the two-phase windings of the stator currents having a frequency of $(n+2)\ f$. These currents having a frequency $(n+2)\ f$ may be collected at the terminals a^1, b^1, d^1, after the capacities C^2, C^2, which, being combined with the capacities C^1, C^1, eliminate the self-induction of the windings of the stator for the frequency $(n+2)\ f$. In this manner, while currents having a frequency $n.f.$ are introduced from the exterior through the terminals a, b, d, currents having the higher frequency $(n+2)\ f$ can be collected at the terminals a^1, b^1, d^1 for the desired purpose. These currents having a frequency $(n+2)\ f$ may in turn be converted into currents having a frequency $(n+4)f$, and so on by the same method either in another machine or in another part of the periphery of the same machine. (*Accepted December* 8, 1915.)

5554/15. The British Westinghouse Electric and Manufacturing Company, Limited, London. Electric Meters. [2 *Figs.*] April 15, 1914.—The invention relates to electrical measuring-instruments, and particularly to motor meters for use in connection with alternating-current circuits. An object of the invention is to provide an improved electrical measuring-instrument of the induction type in which a permanent magnet surrounds a cylindrical armature and serves the double purpose of acting as a return path for the electro-magnetic lines of force and as a damping magnet. A magnetisable core member 1 has a plurality of polar projections 2, 3, 4 and 5, which are spaced apart, and around which are disposed the current windings 6 and 7. A voltage winding 8 is disposed upon the central leg 9 of the magnetisable core 1. The free ends of the projections 2, 3, 4 and 5 and the opposite portion of the body portion of the magnetisable core 1 have a substantially cylindrical formation. A light-weight metal cylinder 10 is open at its lower end and is provided with a plurality of arms 11 at its upper end, which terminate at its central axis for supporting the same. The cylindrical member 10 constitutes the armature of the motor and is disposed around the magnetisable core 1 substantially as shown in the drawing. A permanent magnet 12 of substantially annular form is disposed around the rotatable armature 10 for the double purpose of acting as a return path for magnetic lines of force from the magnetisable core 1 and as a damping magnet for the armature. The poles 13 and 14 of the magnet 12 are located adjacent to the cylindrically-curved end of the magnetisable member 1. A soft-iron member 15 is attached by a screw 16 to the magnet 12 adjacent to the polar projections 2, 3, 4 and 5. A member 17 is attached to the opposite sides of the magnet 12 by screws 18 and extends within the armature 10 to support the magneti-able member 1, which is attached thereto by screws 19, and to support the armature at a point 20 which coincides with its central axis. A member 21 is also attached to the magnet 12 by the screws 18 to serve as a guide for the shaft 22 of the armature 10. The shaft 22 is associated, at its upper end, with an integrating mechanism, the dials 23 of which co-operate with pointers 24 for the purpose of registering the rotations of the armature. The windings 6 and 7 are usually connected in series relation to the conductors that carry the energy to be measured, and the winding 8 is usually connected in shunt relation to such conductors. Since there is a relatively large number of turns in the winding 8, the current flowing through the same will not be in phase with the current flowing through the windings 6 and 7, which have a relatively small number of turns. The two magnetic fluxes that differ in

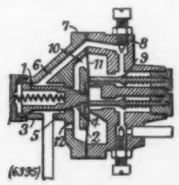




phase will pass from the polar projections 2, 3, 4 and 5 through the armature to the member 15, and, by reason of their phase relation, will cause the armature to rotate. The magnetic lines of force, after intercepting the armature, pass through the magnetic circuit provided by the permanent magnet 12 to the opposite end of the magnetisable core 1. Since the member 12 is a permanent magnet, a local magnetic circuit will also be established from the poles 13 and 14, through the armature 10, the cylindrically-curved end of the magnetisable member 1 and an air-gap 25 between the said poles to damp or retard the rotation of the armature. The shifting field set up in the air-gap between the member 15 and the polar projections 2, 3, 4 and 5 is identical with the field set up in other instruments of the induction type, and hence needs no further explanation. (*Sealed.*)

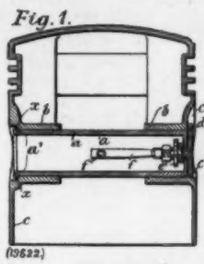
GAS-ENGINES, PRODUCERS, HOLDERS, &c.

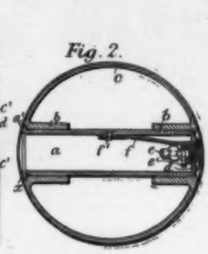
6395/15. J. Keith and G. Keith, London. Automatic Control for Gas-Lamps. [5 *Figs.*] April 29, 1915.—The invention relates to automatic lighting and extinguishing apparatus for high-pressure gas-lamps, such as described in Specification No. 4290, of 1914, and has for its primary object to provide means for preventing gas, which has leaked past the valve controlling the pilot-light by-pass, from passing to the pilot-tube while the lamp is alight, thereby preventing deposition of carbon in the pilot-tube. According to the invention, there is provided a passage which is out of communication with the gas supply when the pilot-light is in use, but is adapted to permit escape to the atmosphere of any gaseous leakage entering the pilot supply while the lamp is alight. The spindle 1 of the plunger 2, in lieu of being guided along its entire length as heretofore, has a sliding fit with the outer end only of the spindle-guide 3, and at its inner end is tapered to form a conical valve portion 4, adapted, when the plunger 2 is in its innermost position, corresponding to the closed position of the main valve, to seat on the contracted inner end of the guide 3, there being thus afforded between the spindle-guide 3 and the spindle 1 an annular space 5, which is maintained closed at the outer end, but which is open at the inner end during such time as the conical portion 4 is unseated. Leading to the annular space



5 is a passage 6 extending through the cap member 7 of the diaphragm-casing into the casing proper 8, and communicating with the pilot-light supply. In the outward position of the plunger 2, corresponding to the open position of the main valve, and to the interruption of the supply to the pilot-light by the pilot-supply control-valve 9, the annular space 5 is brought into communication with the chamber 10 formed in the cap member 7 at the back of the diaphragm 11, which chamber 10 is formed with a small vent 12 open to the atmosphere. Accordingly, any leakage of gas past the pilot-supply control-valve 9 and through the passage 6 to the annular space 5 can now pass by way of the vent 12 to the atmosphere. It will be appreciated that with the spindle 1 guided in a comparatively narrow bearing, in lieu of being in a bearing for substantially its entire length, friction due to the eccentricity thereto of the pilot supply-control valve and of the enriching supply-control valve is diminished, inasmuch as, although these valves tend to tilt the plunger and spindle, the extent of tilting movement is limited by reason of the plunger being held in a central position by its frictional engagement with the diaphragm 11. Moreover, in the event of the plunger being displaced from its central position when retracted, it will be restored to its central position by the engagement of the conical valve portion with its seat. (*Sealed.*)

13,622/15. F. H. Royce and Rolls-Royce, Limited, Derby. Gudgeon-Pin Locking Devices. [3 *Figs.*] September 24, 1915.—This invention relates to an improved method of, and means for, securing the gudgeon-pins of internal-combustion engines, particularly engines for motor vehicles, aeroplanes, and the like, which are usually fitted with pistons of light construction, having thin walls. According to this invention, a hollow gudgeon-pin is provided having a shoulder at one end and carrying a locking-plate at the other end, the said locking-plate engaging recesses both in the piston and in the pin. The hollow gudgeon-pin a is shown fitted into the usual type of bosses b formed integral with the piston c, the gudgeon-pin being suitably shaped at one end to allow of fixing the locking device, whilst at the opposite end a suitable shoulder a^1 is formed, locating the gudgeon-pin endwise. The locking device consists of a tongued piece d fitted across one end of the gudgeon-pin, and tapped to accommodate a screw or set-pin e. The tongued piece d is fixed into slots c^1 cut in the piston c, and also slots or the equivalent formed in one with the gudgeon-pin. When the screw or set-pin e and tongued piece d are in position, the gudgeon-pin is prevented from rotating, and is only allowed a predetermined small amount of movement endwise. Any suitable device may be used to lock the screw or set-pin e. For instance, a flange e^1 may be formed integral with the set-pin, this flange being slotted to accommodate the end of a spring-finger f, which spring-finger is fixed to the gudgeon-pin by means of the rivet f^1. The spring-finger f is arranged to press against and drop into one of the slots formed in the edge of the flange e^1, thus making it impossible for the screw

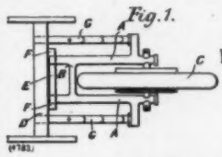


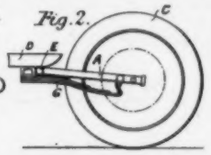


or set-pin e to turn until the end of the spring-finger f—which projects through the gudgeon-pin a—is held out of engagement with the slotted flange e^1. The screw or set-pin may be turned by means of a box or tube-spanner inserted from the open end of the gudgeon-pin. It should be observed that a clearance x is left between the inside of the shoulder a^1 of the gudgeon-pin and the piston c, the object of this being to allow the gudgeon-pin to float between certain small predetermined limits, and in this manner to prevent the gudgeon-pin securing device from distorting the piston. (*Sealed.*)

MOTOR ROAD VEHICLES.

4782/15. The Williamson Motor Company, Limited, and W. Williamson, Coventry. Three-Wheeled Motor Vehicles. [3 *Figs.*] March 27, 1915.—This invention relates to the suspension of three-wheeled motor and other vehicles, and it has for its object to prevent swaying of the body or frame, which usually occurs with three-wheeled vehicles. According to this invention, a pair of radius-bars are employed and connected together so as to form a single stiff frame carrying the wheel-

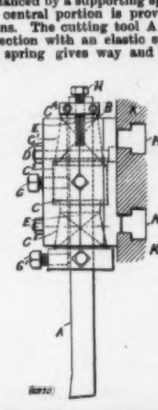




spindle, and this frame is provided with a single very long bearing on a pin or the equivalent upon the main frame. The two radius-rods A are joined together by the bridges B and E in such a way that a stiff frame carrying the spindle of the rear wheel C is provided. This is pivoted to the main frame D by means of a single long bearing within the bridge E, which is mounted upon a pin or the like carried by, and extending between, the brackets F on the main frame. At each side of the rear frame formed by the parts A, B, E is a quarter elliptic spring G carried at the forward end by the main frame, and shackled at the rear end to the rear frame. (*Sealed.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

2970/15. Joshua Buckton and Co., Limited, J. H. Wicksteed, and C. W. James, Leeds. Tool-Holders. [4 *Figs.*] February 24, 1915.—This invention relates to tool-holders for slotting and like machines, of the type in which the cutting-tool is attached to a central portion having a pyramidal formation, which acts as guiding-feather as well as relieving inclines, and in which the weight of the cutting-tool and its connected parts are balanced by a supporting spring. According to the invention, the central portion is provided with two such pyramidal formations. The cutting tool A is so mounted and suspended in connection with an elastic spring B that on the return stroke the spring gives way and allows the previous

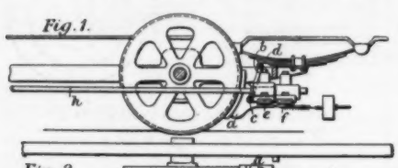


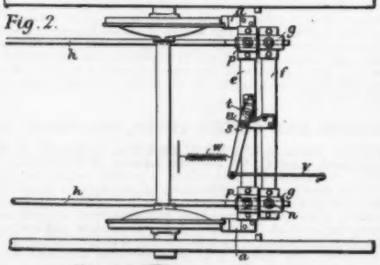
mounting to release itself by slightly falling away from its guides. The form of tool-holder which accommodates the greatest variety of tools is the following. In this the tool itself A, preferably rectangular in the cross-section of its shank, is firmly fixed in a sleeve C, at the head and foot of which are arranged upper and lower pyramidal zones C^1 and C^2. These upwardly converging portions are carefully, in their turn, bedded in similar pyramidal surroundings in an outer sleeve D, which forms the tool-box. This tool-box D, instead of being made solid, is divided longitudinally down and along its centre E, E, and that preferably in a plane parallel with the front of a tool-box when arranged ordinarily. This plan of dividing the tool-box, besides making it

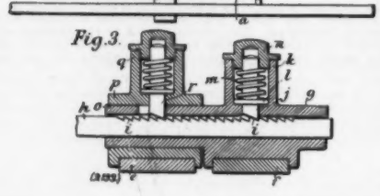
easier to obtain the specially good fitting required, allows the central portion C^3 of the inner sleeve to be made larger (diametrically) than would otherwise have been possible had one sleeve to be threaded through the other. The spring arrangement is preferably a dual one, in order that the tool-shank may, when its length demands it, pass freely through between the springs. The cutting-tool A is ordinarily secured by set-screws G, two or more passing through the enlarged central portion of the inner sleeve at C^3, whilst others G^1 are passed through the enlarged central portion of the inner sleeve at C^3, whilst others G^1 are passed through an enlargement formed below the lower pyramidal zone. This arrangement has the advantage of leaving the head of the tool-box, &c., free for the reception of the spring-balancing gear, whose function is to lift and bring back the tool with its inner sleeve and pyramidal zones up to the working position, at the top of each stroke. The spring strength need not be much more than a balancing one, as the inertia of the tool, &c., assists in bringing about the action and reaction when at work. A quick-return motion renders the inertia still more effective, but at any rate the spring-gear is preferably adjustable to allow it to be turned to its requirements. C^4 are brackets at the head of the upper pyramidal sleeve C^1, and these carry set-screws H, H, whose feet press against the compression springs. The springs are pocketed below in the outer casing, and by the screws H, H any desired upward pressure is transmitted to the tool-holding sleeve. The end of the slotting-head is shown at K, K, and at K^1, K^1 are the usual grooves for taking the fixing-bolts. (*Sealed.*)

RAILWAYS AND TRAMWAYS.

2133/15. J. W. Gibson and J. H. Gibson, Sale. Tramcar Brake Gear. [3 *Figs.*] February 10, 1915.—This invention refers to brake mechanism as used on tramcars and other vehicles, wherein the brake-blocks are supported on a bar or bars sliding on the brake-rods and normally held in the "off" position by springs. With such an arrangement it is necessary to make adjustments for wear of the blocks, and this is usually effected by adjusting the position of the slide-bars on the brake-rods, the latter being formed with screw threads and provided with nuts for the purpose. Such adjustments are effected periodically, generally when the tramcar or other vehicle is in the shed, and the object of the present invention is to automatically adjust the slide-bars as the brake-blocks wear, thereby rendering the brakes more reliable in use and manual adjustments unnecessary. According to this invention, the usual brake-rods and slide-bars may be used, the former, however, being provided with rack teeth, and the latter with spring-pressed pawls or plungers engaging with said rack teeth. The arrangement is such that the pawls or plungers on the sliding bars serve to limit the rearward movement of the same, on the brake-rods, relatively to the wheels, whilst allowing the brake-rods to advance and automatically to take up wear, a spring or springs usually being provided to draw the two bars together and pull the brake-blocks off. The brake-blocks *a* are supported by the links *b* pivotally connected thereto at *c* and to the rod *d* carried by the framework of the truck. One brake-block is usually applied to each wheel, and the pair used in conjunction with the pair of wheels on each axle are connected to a common slide-bar *e*. A second slide-bar *f*



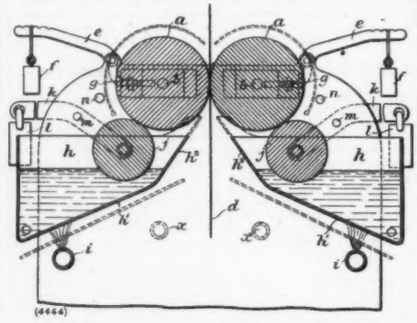




is mounted alongside the first in the usual manner, and provided with bearings *g*, *g* to receive the brake-rods *h*, *h*. The latter are formed with teeth *i*, in which engage spring-pressed plungers *j*, mounted in casings *k* on the bearings *g*. Each plunger *j* is formed with a collar *l*, against which bears a spring *m*, the top end of which bears against a nut or gland *n* bored to receive and position the top end of the plunger. An extension *o* on each bearing *g* passes through a member *p* fixed to the slide-bar *e*, the said member also being formed with a casing *q* to receive a second spring-pressed plunger *r* mounted and operated in a similar manner to the plunger *j*. A floating lever *s*, which is pivoted at *t* to the bar *e*, and at *u* to a bracket on the bar *f*, is operated through the draw-bar *v* by a chain, from a rotating barrel in front of the car in the usual manner, a spring such as *w* being provided to return the bars to the closed position, when the operator releases the pull, and, if desired, the usual springs may be provided to act upon the brake-block. In trucks of the kind referred to, two sets of brake-blocks are coupled together by rods *h*, *h* through their respective slide-bars *f*, and the operation of the apparatus is as follows:—When the lever *s* is manipulated to apply the brake, the inner end of the same acts about the fulcrum *u* to separate the bars *e*, *f*, with the result that the slide-bar *e* carrying the brake-blocks *a* moves towards the wheels, the plunger *r* riding up the inclined tooth, the bar *f* being prevented from moving rearwardly owing to the plunger *j* engaging one of the teeth *i*. Immediately the blocks *a* engage the wheels and the motion thereof is arrested, the slide-bar *f*, together with the brake-rods *h*, *h*, are forced outwardly, thereby applying the brake-blocks to the opposite set of wheels, continued pressure on the lever *s* reacting on all the brake-blocks equally. The normal travel of the brake is less than the length of one tooth *i*, and when the brake-blocks wear away so much that the length of travel exceeds one tooth, the plunger advances into the next notch, thereby automatically compensating for the wear. When the pull on the draw-bar *v* is removed by the operator, the slide-bars *e*, *f* tend to meet under the influence of the spring *w*, which draws the plunger *r* firmly into engagement with the tooth *i*, upon which it then rests, after which the bar *f* is drawn towards the bar *e*, and if the latter has advanced a tooth, the former also advances a tooth, thereby automatically maintaining approximately the same distance of travel of the brake-blocks and the same distance between the two slide-bars, notwithstanding the wear upon the brake-blocks. (*Sealed.*)

TEXTILE MACHINERY.

4444/15. H. D. Herring and H. Harrison, Manchester. Textile Printing-Machines. [1 *Fig.*] March 22, 1915.—This invention refers to printing-machines as used for printing in wax, or the like, upon textile material, the invention being chiefly applicable to machines for printing upon both sides of the material simultaneously, although also applicable to machines for printing upon one side only. According to this invention, instead of printing-rollers being heated internally, as heretofore, they are heated externally and in such manner that the heat is primarily applied to those portions of the surfaces of the rollers forming the sides of the angle below the point where the rollers contact with the fabric. *a*, *a* are the two printing-rollers, each mounted to rotate freely in adjustable end bearing-blocks *b*, *b* in the end of the frames of the machines. These rollers are of uniform size and are provided with the usual printing surface for printing in wax or the like. The rollers are arranged to right and left of the fabric to be printed, such fabric, marked *d*, passing upwards between the rollers, while the rollers are pressed against the opposite faces of the fabric with an equal pressure. For this purpose the levers *e* and adjustable weights *f* are provided, each lever pressing, by preference, against the head of a screw *g* in the bearing, which allows of the same levers being used for different sizes of printing-rollers. Below each printing-roller is a wax-holding tank *h*, preferably made of sheet metal, and having a sloping floor part h^1, and also an inclined side wall h^2. Below each tank is a multi-jet gas-burner *i*, by which the tank may be



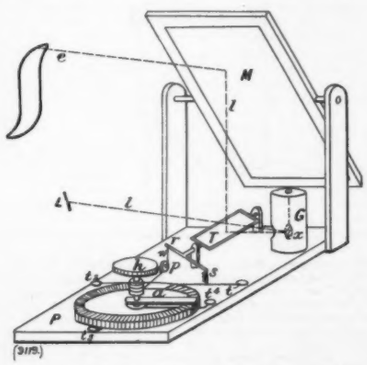
heated and its contents melted. Within each tank is a furnishing-roller *j*, the axis of which is carried by levers *k* provided with counterweights *l*, by which the roller is held yielding in contact with the printing-roller. The levers are mounted on studs *m*, carried by the end frames of the machine, and to allow of the same furnishing-roller being used with different sizes of printing-rollers, the studs are transferable from one set of holes *n* to another set formed in the end frames of the machine. The sloping floor part h^1 and the inclined side wall h^2 of each tank incline or slope upwardly and collectively produce between them a space, the sides of which virtually form two sides of a triangle. Further, in conjunction with the end frames of the machine which lie close to the ends of the rollers, a pocket or chamber is produced. In thus forming and arranging the tanks, the heat from the gas-burners *i*, on rising, is directed into the angle between the printing-rollers, thereby causing those portions of the rollers approaching and touching the fabric to be effectively heated and the wax kept melted until it is imparted to the fabric. As each printing-roller revolves it carries the heat around with it, and thus ensures the whole surface of the roller being heated. To allow of a fairly large burner being used and to prevent the undue heating of the wax, a baffle-plate (as shown dotted) may be arranged below each tank. Further, to guard against the wax spilling over the top edge of the sloping end h^2 of the tank, the edge may be extended upwards and nearer to the fabric, as shown by dotted lines. In lieu of heating the printing-roller or rollers by the same gas-burners which heat the wax-holding tanks, separate or additional gas-burners may be used, arranged, say, where shown by the dotted lines at *x*. (*Sealed.*)

MISCELLANEOUS.

4368/15. R. F. Carey, Leigh-on-Sea, and Waygood-Otis, Limited, London. Hose-Pipes. [2 *Figs.*] March 19, 1915.—This invention relates to improvements in joints or connections for hose-pipes and the like, and is particularly applicable to the hose connections employed in vacuum cleaning-apparatus. According to this invention, metal or similar stiffening tubes are inserted into and project from the ends of the pipe sections, the said tubes being provided exteriorly with rubber or the like sheathings, the sheathing of one tube being adapted to be

wedged into the other tube. The hose is shown at *a*, a^1, *b*, b^1, being sections of metal tube inserted and solutioned or cemented into the ends of the hose so as to project therefrom. The tube *b* is cylindrical, but tube b^1 is flared outwardly where it projects from the hose, as shown at b^2. The metal tubes are provided externally with hard rubber sheathings *c*, c^1, the one *c* being coned exteriorly to fit into or be wedged into the flared end b^2 of the tube *b*. The rear ends of the sheathings *c*, c^1 overlap and embrace the hose *a*, a^1, and, as shown in Fig. 2, those rear ends may be undercut if desired. The tube *b*, which is provided with the sheathing *c*, may have a rounded shoulder or flange at its extremity to prevent the forward end of the sheathing *c* from being forced back. The above joint affords a neat finish to the hose; the latter is strengthened and stiffened by the tubular metal or similar insertions, and the rubber sheaths not only protect the hose and tubes, but also prevent damage to furniture and the like. (*Sealed.*)

3119/15. J. A. Fleming, London. Optical Delineation of Physical Curves. [4 *Figs.*] February 28, 1915.—This invention relates to improvements in the means for projecting and photographing curves representing the variation of magnetic or electric forces, currents, fluxes, voltages, or potentials. It is desirable and necessary in many physical observations to describe such a curve with horizontal distances or abscissæ denoting one variable electric or magnetic quantity and vertical distances or ordinates, some other related electric or magnetic quantity, and it is desirable to be able to project and render visible such a curve by means of a spot of light moving over a screen, and to photograph the curve and record it permanently. According to this invention, an instrument for the optical delineation of physical curves comprises a mirror capable of being tilted round a horizontal axis by the rotation of a shaft which varies proportionately to an electric potential, capacity or resistance, combined with a mirror capable of being rotated round a vertical axis, the displacement of the last-named mirror being proportional to the variation in a correlated magnetisation, current or voltage. The instrument consists of a base-board on which is fixed a rectangular mirror T which is pivoted on a horizontal shaft and held in bearings so as to rock or tilt about a symmetrical axis parallel to the length of the mirror. This mirror should be formed of flat plate-glass silvered on the front surface, so as to avoid "ghosts" or duplicate reflections. The axis on which this mirror rocks has on it at one end a bar *r*, to one extremity of which a spiral spring *s* is attached, the other end of this spring being fastened to the base-board. To the other end of this lever *r* a thread *w* is tied which passes under a pulley *p*. If this thread is pulled, the mirror T is tilted over through a certain angle. The normal position of this mirror is with its reflecting surface at 45 deg. to the horizontal plane. Over the tilting mirror T is fixed another larger mirror M slung on a horizontal axis between supports. The normal position of the mirror M is with its reflecting surface directed down towards the tilting mirror T, and with its plane at about 45 deg. to the horizontal. The axis of the mirror M is at right angles to that of the mirror T. On the base-board or near to it is placed some reflecting deflectional instrument, such as a mirror galvanometer, magnetometer, or electrometer G, according to the nature of the curves to be delineated. An arc-lamp L is placed on the opposite side of the base-board, so as to send a beam of light which may be rendered parallel by suitable lenses just above and across the tilting mirror T. This beam falls on the mirror *x* of the instrument G. This last mirror is preferably a concave mirror of worked glass, silvered on the front. The beam of light *l* is focussed



so as to pass just over the tilting mirror T, and to be caught by the mirror *x*, sent back on the tilting mirror T, and then reflected upwards on to the mirror M, and thence on to a vertical screen at a distance, and there to form a sharp small brilliant spot of light. It will be evident, then, that if the mirror T is tilted over through a small angle which is not great enough to cause the ray of light *l* to pass off the mirror M, that the spot of light on the screen will move horizontally by a distance proportional to the angle of tilt of the mirror T. Again, if the mirror T remains stationary, and the mirror *x* of the instrument G executes a deflection round its suspension, the ray of light *l* will so move as to cause the spot of light on the screen to make a vertical movement proportional to the angle of deflection of the mirror *x*. Hence the two independent motions of the tilting mirror T and the mirror *x* cause the spot of light to possess two independent motions at right angles to each other. These motions are communicated as follows:—On the base-board of the instrument is a circular potentiometer P. It consists of a ring of wood wound over with cotton or silk-covered high-resistance wire, such as manganin, constantan, or "Eureka" wire in one layer of closely adjacent turns, the winding extending almost the whole way round the ring. The silk or cotton covering is rubbed off the wire on the top side of the ring so as to expose the bare wire. The ring is fixed down on the base-board, and at its centre is fixed a vertical rotating axis which carries a head *h* at the top, and a metal radial arm *a*, the end of which rotates and makes contact with the exposed turns of the wire winding on the hoop as the head *h* is turned. The wire winding has its ends attached to two terminals t^1 and t^2, and a third terminal t^3 inserted at its middle point. There is also a terminal t^4 which is in electrical connection with the arm *a*. If then a battery B of a certain number of cells has its terminals attached to t^1 and t^2, it will cause a current to flow through the potentiometer wire and a fall of potential to take place down it. If the rotating arm *a* is placed in any position, a certain fraction of this battery potential will be created between the terminals t^3 and t^4, which will have magnitude and direction according to the position of the arm. On the axis of rotation of this arm there is a barrel, round which the thread *w* is wound, and the size of this barrel must be so adjusted that when the potentiometer arm *a* is rotated from one extreme position to another at the ends of the potentiometer wire it will tilt over the rocking mirror T just sufficient to displace the ray of light from one side to the other, whilst still keeping it falling upon the mirror M. Accordingly, when this is done, the horizontal displacement of the spot of light on the screen will be proportional to the angle through which the head *h* is rotated, and this again is proportional to the potential difference produced between the terminals t^3 and t^4. (*Sealed.*)